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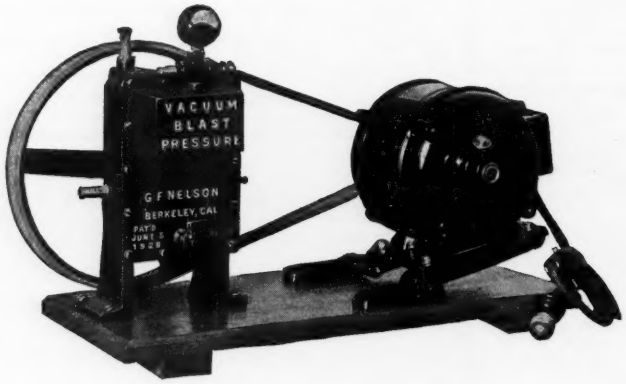
THE NEW NELSON VACUUM AND PRESSURE PUMP



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ARNOLD FREDERIK HOLLEMAN

A. F. Holleman, Nestor of the Dutch chemists, was born on August 28, 1859, at Oisterwyk, Netherlands. Trained at Leiden, Heidelberg, and Munich, he was appointed assistant to van't Hoff at Amsterdam in 1887. His talents were soon shown to be worthy of more responsibility, and in 1889 Holleman went to Groningen as director of the agricultural laboratory. Another advancement was not long in coming and in 1893 he was made professor of chemistry in the University of Groningen and filled this post with such distinction that in 1905 he was called to Amsterdam as professor of organic chemistry. He retired from active teaching in 1924.

Of his numerous contributions to chemical literature, the first rank is taken by his studies of substitution in the benzene ring, and he collected his authoritative knowledge of this important subject in his well-known volume: "Die Einführung von Substituenten in den Benzolkern."

Honors have come to him not only in his own country, but also from the Institut de France (corresponding member), St. Andrews, Leeds (honorary doctorates), etc. Chemical students throughout the world know his name, for Holleman's texts of both inorganic and organic chemistry have passed through many editions in nine languages. (*Contributed by Ralph E. Oesper.*)

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EDITOR'S OUTLOOK

THE PERFECT AUTHOR. Our recent guest editorial writer presented us with an idea as well as an editorial. If tribute is to be paid to the ideal small college professor, why not a word for the ideal author also?

It may be taken for granted to begin with that the sort of author who gladdens an editor's heart has something to say, that he organizes his presentation logically, that his expression is economical and grammatical, and that his orthography (especially in the matter of names) is irreproachable. His manuscript never gives the impression of having been "dictated but not read."

Even so much is a great deal to take for granted, and any editor fortunate enough to be able to award all his authors a perfect grade in these fundamentals has more cause for gratitude than repining.

On second thought, it is perhaps a mistake to dismiss the subject of grammar and good literary usage so lightly. The ideal author avoids certain faults that are so prevalent among scientific and educational writers as to warrant particular mention. For instance, he uses the word data sparingly, and he never forgets that it is plural. He remembers that per cent. is an abbreviation of *per centum*, and he uses it in that sense only. Similarly, he understands the other abbreviations he employs; he does not write *i. e.* when he means *e. g.* In describing experimental procedures he remembers that one adds reagents—not grams or cubic centimeters. Hence he never writes: "Five grams of benzene *were* added . . ." He avoids the use of a figure at the beginning of a sentence. He does not write "strong" acid when he means "concentrated" acid, nor "weak" alkali when he means "dilute alkaline solution." He never "takes a mixed melting point"; rather, he determines the melting point of a mixture. He does not consider the final words "as follows" sufficient justification for concluding a sentence with a colon. He never refers to "the above," for, aside from deploring the use of above as a noun, he realizes that what went before may not be "above" when it gets into print.

It is in the ability to visualize his material in print, and to make due allowance for the mechanics of putting it there, that the ideal author outstrips the field. The ideal author realizes that tabulated material run directly into his text would be unsightly in any case, and that it assumes the risk of division at the bottom of a column. He therefore sets up his tabulations as independent, completely headed units, and refers to them in his text by the proper table numbers. He does not undertake to say that a given tabulation will appear "below," for he cannot know that. In all cases where any possibility of doubt exists he specifies the units in which his figures are expressed. If there is more than one satisfactory way of setting up his tabulation he chooses the way that best accords with the page or column dimensions of the publication for which he is writing.

He displays similar discrimination in drafting diagrams and graphs, and he makes the frames of his graphs no larger than is necessary to enclose the curves presented. He realizes that line-thicknesses undergo the same proportionate reduction as the other dimensions of his drawing, and he does not make the mistake of inking so lightly that his cut is in danger of breaking down during the press run. He also realizes that unless he is expert indeed the typesetter can make a better job of lettering than he can, and he plans his graphs so that as much of the necessary explanatory lettering as possible may be set in type outside the borders of the cut. Although he counts upon reduction to obscure minor imperfections of line to some degree, he does not expect reduction to improve ill-formed lettering or sloppy drafting. He does not forget to supply adequate captions.

He knows that even a perfectly written manuscript requires some typographical annotation, and he sees to it that his typist uses adequate spacing and leaves ample margins for that purpose. If he inserts typographical indications of his own he makes sure that they are consistent with the style of the publication for which he is writing, and he uses the correct symbols—a single underline for italics, a double underline for small capitals, a triple underline for capitals, and a wavy underline for boldface.

He corrects proofs carefully and returns them promptly. If he does not know the proper proofreader's symbol for a correction he contrives to indicate it without ambiguity, and carries his indication into the margin where it may be seen. He does not remove a superfluous comma with his penknife. Neither does he undertake extensive revision of his article in proof.

In short, he is to all editors a joy forever. We are fortunate in knowing a few members of the species, whom we salute. May their tribe increase.

PRIESTLEY, LAVOISIER, *and* TRUDAINE DE MONTIGNY

RALPH E. OESPER

University of Cincinnati, Cincinnati, Ohio

IN THE preface to the second volume of his "Experiments and Observations on different kinds of Air,"[1] Priestley wrote:

"I am very sorry to have had occasion to insert in this volume a particular section on the *mistakes* that have been made with respect to my Observations and Experiments by several foreign philosophers. But they are so many and so gross and made by persons of so much reputation, that I have thought it necessary to do so both on my own account and also to obviate such misrepresentation of *facts*, as might retard the progress of philosophical knowledge. For these mistakes foreigners may plead the want of a perfect knowledge of the English language, and in some measure the plea may be admitted, though every person should take care to make himself fully acquainted with what he proposes not only to understand but to explain to others."

This complaint is directed especially against Lavoisier who, in his *Opuscules Physiques et Chimiques* (1774), had made so many misstatements of what Priestley had written, that even though the latter had filled four pages with them he still felt impelled to write, "I shall not even think it worthwhile to note all the mistakes of Mr. Lavoisier, and I shall be as concise as possible in my remarks, exhibiting what I have been represented as saying in one column, and what I have really said in another."

Lavoisier did not read English easily and doubtless knew Priestley's work only in translation, but in Priestley's opinion the misrepresentations could not be laid at the translator's door, with whose work he was well satisfied. "Mr. Gibelin[2] who has acquitted himself

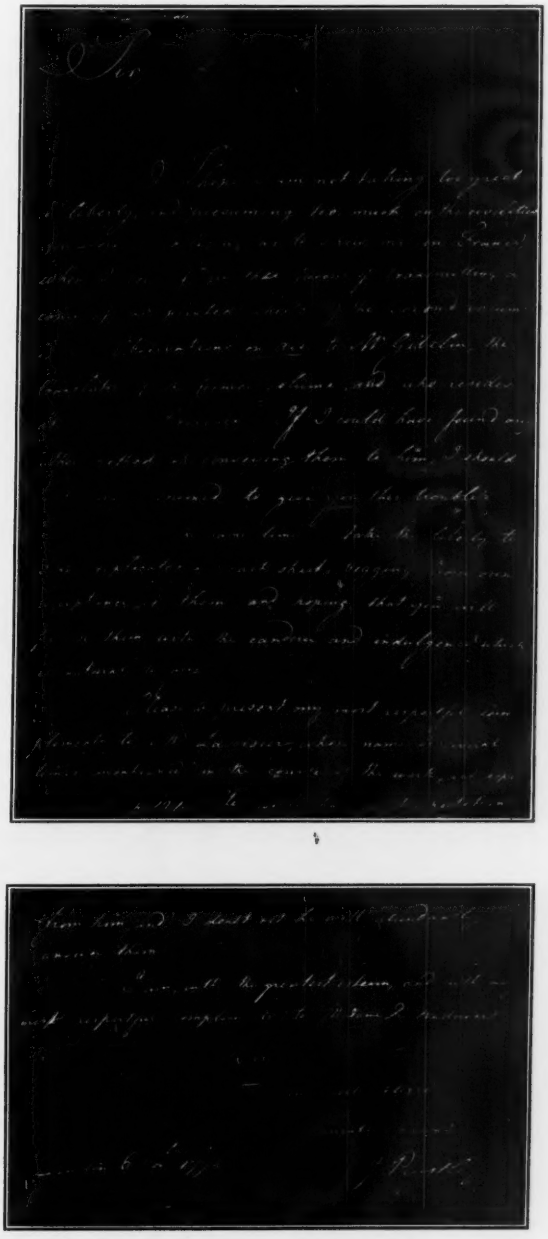


FIGURE 1.—PRIESTLEY'S LETTER TO TRUDAINE DE MONTIGNY

[1] Priestley published his chemical discoveries, including those that had previously appeared in the *Philosophical Transactions*, in six volumes. The first three: "Experiments and Observations on different kinds of Air," appeared in 1774, 1775, and 1777; the second series: "Experiments and Observations relating to various branches of Natural Philosophy with a continuation of the Observations on Air," in 1779, 1781, and 1786. These books were later methodized by the author, compressed into three volumes, and issued in 1790 as: "Experiments and Observations on different kinds of Air and other branches of Natural Philosophy connected with the subject." While the systematized work is better as a book of facts, the original accounts which he put out in the time order of his discoveries are preferable for historical studies.

[2] Jacques Gibelin (1744–1828) studied science in Paris and then medicine in London. The rest of his life was spent at his native city, Aix, where he was municipal librarian and permanent secretary of the Society of Agriculture, Sciences and Arts. His translations from English include Kirwan's "Mineralogy," Franklin's "Autobiography," medical works, extracts from the Philosophical Translations, etc. The translations of Priestley's volumes appeared in five volumes: "Expériences et Observations sur différentes Espèces d'Air," 1 (1775), 2, 3 (1777), 4, 5 (1780). The last two, covering Volume 3 of the English, contain notes by the translator. Only the first volume of Priestley's second series was translated: "Expériences et Observations sur différentes Branches de la Physique avec une Continuation des Observations sur l'Air," 2 vols., 1782. A long preface was added by the translator.

so well[3] in the translation of the first volume of this work, has undertaken the second. I have, at his request, already sent him the printed sheets." With the sheets was sent a letter (Figure 1) which, by some trick of fate, has been preserved and is now in the collection of the late Lyman C. Newell. It is addressed to Mr. Trudaine, who was asked to forward the sheets to

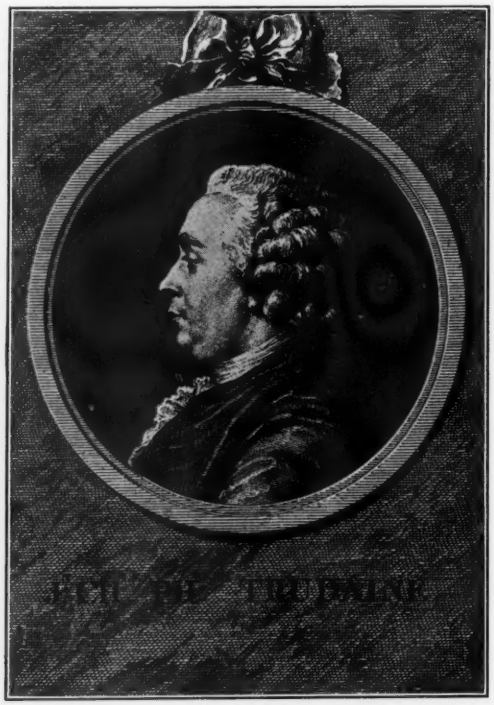


FIGURE 2.—TRUDAINE DE MONTIGNY
Engraved by Saint Aubin from a drawing by Cochin.

Gibelin. The postal service was slow, expensive, and uncertain, but Priestley knew that Trudaine, as administrator of highways, was in a favored position to forward letters and parcels to even the outskirts of the kingdom, and Aix in Provence was a very long distance from Paris in those days. This letter is of interest not only because of its connection with Priestley's book, but particularly because of the reference in it to Trudaine's dear friend, Lavoisier, to whom Priestley sent his compliments together with the prediction, "the world has great expectations from him and I doubt not that he will abundantly answer them." Note the similarity of this phraseology with that on page 121 of the sheets to which Priestley calls Trudaine's special attention. He there describes a striking demonstration of the burning of great jets of nitrous ether (impure ethyl nitrate), "an experiment which I had the pleasure to see at Paris in the laboratory of Mr. Lavoisier, my excellent fellow labourer in these inquiries, and to whom in a variety of aspects the philosophical world has very great obligations." Priestley allowed Trudaine to discover for himself the passages in which Lavoisier was mentioned in much less complimentary terms, likewise the passage (see below) in which he spoke highly of Trudaine's hospitality.

Priestley's "Mr. Trudaine," known in France as Trudaine de Montigny (Jean Charles Philibert) (Figure 2), was born in 1733, the son of that most able official, Daniel Charles Trudaine (1703–1769), "the grand Trudaine." He was given every educational advantage and trained by his father to be his understudy and eventual successor to his important government posts: Councillor of State, Intendant General of Finances, Director of the Administration of Bridges and Highways. At his father's death, these offices were given to him, but when the King wished him also to fill the vacancy in the Royal Councils of Finance and Commerce, Trudaine begged to be allowed to serve without receiving these additional salaries. Louis XV replied, "Such favors are requested of me so seldom that the singularity of this occurrence makes me unwilling to refuse you." This enlightened and able father and son worked unceasingly for the public welfare, they did what they could to lighten the tax burden of the poor, their conduct of public office was a model of honesty and efficiency. They were not ambitious, their honors and high positions came to them unsolicited, they were not avaricious, and though they were rich they used their wealth wisely and without offensive ostentation. Their most lasting contribution was a system of excellent highways, paved, drained, lined with trees, linking the capital with the chief cities of the provinces. Important bridges also testified to their executive skill. A school of bridges and highways and a corps of engineers were organized by them to make these achievements possible. The Trudaines worked unceasingly to free industry from some of its bonds, they encouraged the merchants and the artisans, and of course as men of intelligence and culture, they were glad to associate themselves with the learned societies.[4] The father was appointed honorary member of the Académie des Sciences in 1743 and took keen interest in its affairs. In 1764, when ill health and the press of other duties made it difficult for him to give this body all the attention he thought it deserved, he

[3] Priestley freely admitted that he spoke French very imperfectly and was not familiar with French chemical terms. His favorable estimate of Gibelin's translation was not shared by others who perhaps were more competent judges. On May 22, 1775, the Rev. W. Turner wrote to the Rev. N. Cappe, "Mr. Lee (London solicitor and like the other two an intimate friend of Priestley) told me that the French translation of the Doctor's Observations on Air is ill done, in so much that the philosophers at Paris could not understand many things, or verify many of the experiments. Therefore, the Doctor was desired to exhibit several of them. For this a meeting was appointed at M. Turgot's, who had an excellent apparatus. Many eminent persons attended, among others, three archbishops. This distinguished assembly was much surprised, satisfied, and delighted with many things the Doctor exhibited." RUTT, J. W., "Life and correspondence of Joseph Priestley," Vol. 1, 1831, p. 257.

[4] Choullier, in the Revue de Champagne et de Brie, Vols. 14 and 15 (1883), has given an excellent, well-documented history of the Trudaine family, emphasizing the last three generations. No mention is made of Lavoisier.

resigned, but the King, with the consent of the Académie, continued his right to attend the meetings and to vote. His son was named to fill the vacancy. These appointments were in the gift of the King and only nobles were eligible to the twelve honorary memberships. The advantages to the Académie and to the honoraries were mutual: certain aristocrats were thus publicly acknowledged as patrons of science even though their interest was often a mere pretense, while they in turn gave tone and prestige to the Académie at a time when the sciences were not strong enough to stand without the support of the upper class of society.[5]

Trudaine de Montigny had a genuine intellectual interest in the work of the Académie, particularly chemistry and physics, preferring chemistry, however, because he thought it more useful to the average citizen. In 1766 he pledged to the Académie 1200 livres (francs) to be given as a prize for the best method of making flint glass, so necessary in the construction of achromatic lenses, but Louis XV, because of the importance of the topic, insisted that he himself be the donor.[6] Trudaine made a substantial contribution when he defrayed the cost (15,000 livres) of the great burning glass, "the Trudaine lens" (Figure 3), constructed for the Académie and used by Lavoisier and others in 1774.[7]

When one of his positions was abolished, the King offered another in compensation, but Trudaine, eager to find time for laboratory experimentation, asked to be excused from any additional administrative burdens. On July 14, 1772, he wrote to Lavoisier, "I am working diligently to become your fellow chemist. I now have a laboratory that I have not left since it was finished three days ago."[8] Trudaine never published

[5] Priestley, at Philadelphia, in 1794, in discussing the relations of the aristocracy to science, said, "The patronage to be met with there is ever capricious and as often employed to bear down merit as to promote it, having for its real object not science or anything useful to mankind, but the mere reputation of the patron, who is seldom any judge of science." RUTT, *op. cit.*, Vol. 2, p. 262.

[6] MAINDRON, E., "Les fondations de prix à l'Académie des Sciences," **1881,** p. 26.

[7] "Œuvres de Lavoisier," **3,** 274; **2,** 423 (1862–65). Though this gift is acknowledged by Lavoisier, the archives of the Académie contain no record of this contribution.

[8] GRIMAUX, E., "Lavoisier, 1743–1794," Alcan, Paris, **1899,** p. 50.

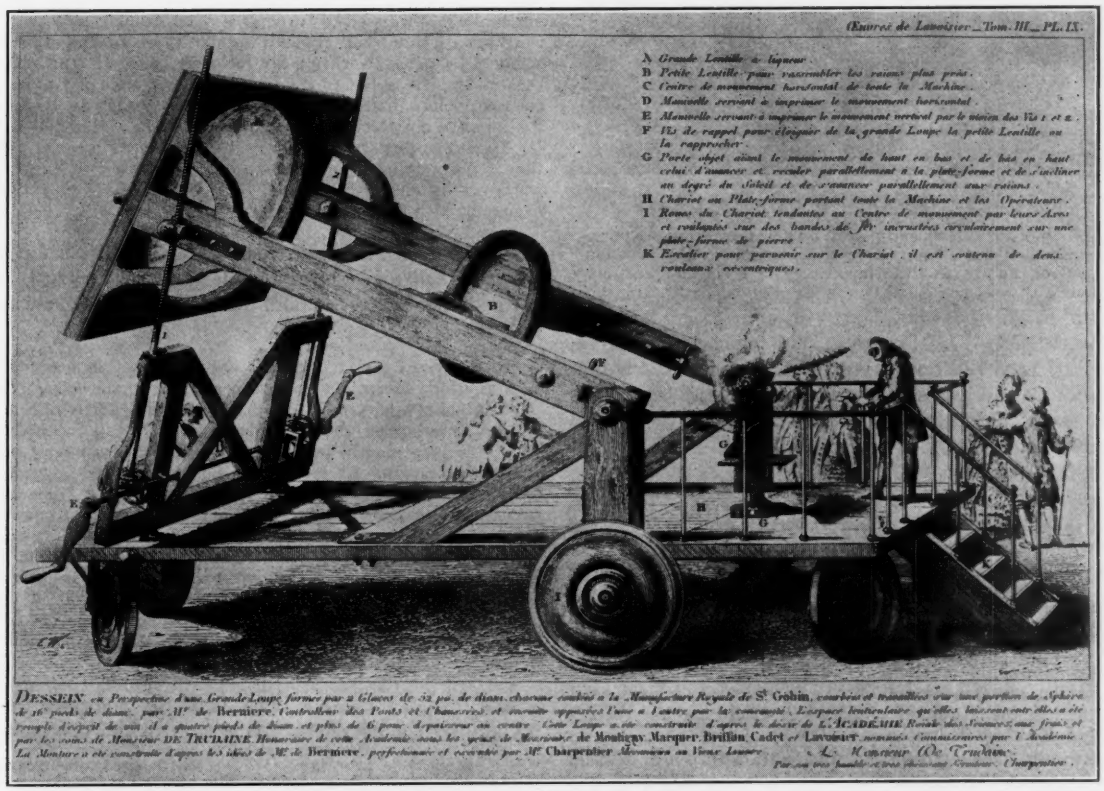

Œuvres de Lavoisier_Tom. III_Pl. IX.
A Grande Lentille à liqueur.
B Petite Lentille pour rassembler les rayons plus près.
C Centre de mouvement horizontal de toute la Machine.
D Manivelle servant à imprimer le mouvement horizontal.
E Manivelle servant à imprimer le mouvement vertical par le moyen des Vis t et z.
F Vis de rappel pour éloigner de la grande Loupe la petite Lentille ou la rapprocher.
G Porte objet ayant le mouvement de haut en bas et de bas en haut celui d'avances et reculer parallellement à la plate-forme et de s'incliner au degré du Soleil et de s'avancer parallellement aux rayons.
H Chariot ou Plate-forme portant toute la Machine et les Opérateurs.
I Roues du Chariot tendantes au Centre de mouvement par leurs Axes et roulantes sur des bandes de fer incrustées circulairement sur une plate-forme de pierre.
K Escalier pour parvenir sur le Chariot il est soutenu de deux rouleaux excentriques.

FIGURE 3.—THE TRUDAINE LENS

The great burning glass or lens, designed and constructed for the Académie by Bernières, Controleur des Ponts et Chaussées, and presented to the Académie by Trudaine de Montigny. It was set up in the garden of the Louvre, on the bank of the Seine. The lenses, 4 feet in diameter, were filled with alcohol (160 pints). Though it produced extremely high temperatures, it was too subject to the vagaries of the sun's brightness, and the discovery of the use of oxygen in blast lamps made this cumbersome apparatus obsolete. An inventory, undated, but just prior to the Revolution, states that the lens had been irreparably broken into four pieces.

anything of chemical importance, but his writings include a eulogy of his father, an anonymous treatise on cattle diseases, a comedy, and a catalog of his father's library, which was sold and dispersed in 1803. He was an ardent advocate of a uniform system of measures and in 1766 secured a royal declaration that the "toise of Peru" be adopted as standard throughout the kingdom, but the Académie nevertheless refused to accept this unit.[9] He planned to put out, with the assistance of others, a natural history of France, and the engineers of the department of bridges and highways were ordered to collect specimens and data. Morellet appraised Trudaine as having "ambitions above his abilities, but nonetheless he was an estimable and worthy gentleman, enlightened, just, and a friend of the better things."

FIGURE 4.—BOWOOD HOUSE, CALNE, WILTSHIRE

Much of Priestley's early work on gases, including oxygen, was done on this estate. One of the rooms in the mansion was long known as "the laboratory." It is now entirely altered.

In August, 1774, Priestley, as companion and secretary to Lord Shelburne, started on a tour of Holland, Flanders, and parts of Germany and France. They reached Paris on September 29 and stayed there until the end of October.

At their first arrival Lord Shelburne carried the Doctor to public spectacles, and the assemblies and routs of the great, but these things were very insipid and irksome to him. He, therefore, asked to be excused. Thenceforward he spent his evenings with parties of literary and philosophical people who flocked to his Lordship's hotel or engaged him elsewhere. . . .

"I have here had opportunity of seeing many of the men who have the chief lead in the direction of affairs, which gives me some pleasure, as I shall have a better idea of them when I read of them in the papers. They are a set of philosophical men, whose object is freedom of commerce and universal peace. . . .I am quite tired of the idleness in which I spend my time here, and long exceedingly to be about my experiments."[10]

Among those whom he met and approved of was Trudaine de Montigny, who, in his town house in the Rue des Vielles-Haudriettes, received the best society of Paris and foreigners of distinction. He invited the two English visitors to his home at Montigny-Lencoup in the old province of Brie. This estate, in the present department of Seine-et-Marne, was then eighteen hours' journey from Paris. The extensive grounds were beautifully laid out with gardens, and the park, planted with rare trees, was ornamented with statues and elegant buildings in keeping with the magnificence of the house. Louis XV once stayed in the château, of whose rich furnishings there is no mention by Priestley, possibly because he was accustomed to similar surroundings at Lord Shelburne's country residence, Bowood House, at Calne, Wiltshire. (Figure 4.)

Priestley tells of this visit in the second volume of his "*Experiments and Observations.*"

"I was in company with Lord Shelburne at the seat of Mons. Trudaine at Montigny, where with that generous and liberal spirit by which that nobleman is distinguished, he has a complete apparatus of philosophical instruments with every other convenience and assistance for pursuing such philosophical inquiries as any of his guests shall choose to entertain themselves with. In this agreeable retreat I met with that eminent philosopher and chymist, Mons. Montigny, Member of the Royal Academy of Sciences,[11] and he proposed our trying to convert oil of vitriol into vapour by boiling it with a pan of charcoal in a cracked phial. This scheme not answering our purpose, he next proposed our heating it with oil of turpentine. Accordingly we went to work upon it and soon produced a quantity of some kind of air confined by quicksilver, but our recipient being overturned by the suddenness of the production of air, we were not able to catch any more than the first produce, which was little else than the common air which had lodged on the surface of the liquor. . . . Having no opportunity of repeating the experiment at that time, I did nothing with a view to it till my return to England, where on the 26th of November, 1774, I resumed the operation, beginning with olive oil."

These experiments eventually led to the isolation of "vitriolic acid air" (sulfur dioxide).

Priestley's impressions of Paris and the French are interesting.

"In this great capital I cannot say that I was much struck with anything except the spaciousness and magnificence of the public buildings, and to balance this, I was exceedingly offended with the narrowness, dirt and stench of almost all the streets. Here I spent a month, but though I was far from having any reason to complain of the reception I met with, and saw many truly polite and agreeable people, I cannot say that I saw any person that appeared to me to be more polite than any I know in England. . . . In general the French are too much taken up with themselves to admit of that minute and benevolent attention to others which is essential to politeness. This appears in nothing more than their continually interrupting one another in discourse, which they do without the least apology so that one half of the persons in company are heard talking at the same time."

Paris was then, as now, the center of French scientific activity and Priestley was cordially received—especially by the chemists. As a professional theologian

[9] FAVRE, A., "Les origines du système métrique," Les Presses Universitaire de France, Paris, 1931, p. 59.

[10] RUTT, *op. cit.*, Vol. 1, pp. 254, 257.

[11] E. Mignot de Montigny (1714–1782), nephew of Voltaire, mathematician and physicist, held the high posts, Trésorier de France, Commissaire du Conseil. Like Trudaine de Montigny (no blood relation) he was especially interested in the application of science to industrial and economic problems. He bequeathed to the Académie 15,000 livres to provide an annual prize of 600 livres for the best proposal of improving some art dependent on chemistry. The prize was never awarded and the principal was taken over by the state when the Académie was suppressed in 1793.

he was interested in the religious sentiment of the French scientists.

"As I was sufficiently apprized of the fact, I did not wonder, as I otherwise should have done, to find all philosophical persons to whom I was introduced at Paris, unbelievers in Christianity and even professed Atheists. As I chose on all occasions to appear as a Christian, I was told by some of them that I was the only person they had met with, of whose understanding they had any opinion, who professed to believe Christianity. But on interrogating them on the subject I soon found that they had given no proper attention to it and did not really know what Christianity was. . . . I always told them very freely that I could easily account for their infidelity by the very corrupted state of their established religion. However, I left them all as I had found them, and whether they think better or worse of me on that account, I am very indifferent. They could not possibly, however, show more respect to anybody, than they did to me, especially on account of my *Observations on Air*, which have engaged the attention of almost all the philosophers on the continent."[12]

Priestley seems to have spent considerable time with Lavoisier, who had a laboratory in his home at the corner of the Rue Neuve des Bons Enfants and the Rue Neuve. (The house was torn down in 1864 to make room for the enlargement of the Banque de France.) He was especially impressed with Lavoisier's demonstration of the preparation and burning of ethyl nitrate.

"At Mr. Lavoisier's I saw with great astonishment the rapid production of I believe near two gallons of air from a mixture of spirit of nitre and spirit of wine, heated with a pan of charcoal; and when that ingenious philosopher drew this air out of the receiver with a pump and applied the flame of a candle to the orifice of the tank through which it was conveyed into the open air, it burned with a blue flame and when working the pump pretty vigorously, he made the streams of blue flame extend to a considerable distance. Being much struck with this experiment, I determined with myself to give particular attention to it and pursue it after my return to England."

Priestley repaid Lavoisier for this interesting exhibition, when he told of the gas he had obtained by heating mercuric oxide.

"Having made the discovery some time before I was in Paris in 1774 I mentioned it at the table of Mr. Lavoisier when most of the philosophical people in the city were present, saying it was a kind of air in which a candle burned much better than in common air, but that I had not then given it any name. At this all the company, and Mr. and Mrs. Lavoisier as much as any, expressed great surprise."[13]

Priestley, in essence, had told all he then knew of the new gas and so had put Lavoisier on equal terms with himself. Because of the use which Lavoisier made of Priestley's disclosure, this dinner has come to be regarded as an historic occasion. The whole question as to the discovery, effective as well as actual, of what Lavoisier eventually named oxygen, has been a perennial subject of discussion and the excellences and shortcomings of the French host and his English guest have been set forth in every possible light, so there is little possibility of any new truth being squeezed from this hackneyed topic. The present narrative will not be burdened with a recapitulation of this too often partisan literature.[14]

The divergent viewpoints are represented by the following, not very well known, passages. Priestley's countryman, Foster, wrote:

"Men will tell you tales of how Priestley, on a visit to Paris, chattered freely to his scientific brother about the experiment which he had just made with his mercuric oxide and his burning glass, they will assert that Lavoisier was then led to his pregnant result. Whether this be true or not does not seem to me to be of vital importance; whether Lavoisier got at his result wholly by himself or not, he and he alone, not Priestley in any way, got at the true meaning of the result, he and he alone discovered oxygen."[15]

On the other side, a Frenchman, well known to students of American history as Citizen Genêt, visited Birmingham in 1783 and met Priestley, who performed for him experiments on air and other gases, "of which I sent an account to the Academy of Paris. On my return, having attended one of the sittings of the Academy, I was surprised to hear the great Lavoisier read a paper which was nothing but a repetition in different words of Priestley's experiments which I had reported. And Lavoisier laughed and said to me, 'My friend, you know it is not always those who start the hare who catch it.' "[16]

Whether true or not, this story agreed with Lavoisier's statement, "I trust that although I have been reproached with having borrowed proofs from the studies of this eminent scientist, at least my title to the conclusions will not be contested."[17] This declaration, made to the Académie on April 6, 1776, probably resulted from Priestley's complaint that Lavoisier, in his paper of April 26, 1775, on the new gas, had not acknowledged the information given at the now famous dinner of October, 1774. These complaints were first aired in the second volume of "Experiments and Observations," and doubtless were pointed out to Lavoisier by Trudaine de Montigny, who, as we know, was in possession of the sheets of this work in November, 1775. Priestley carried his grievance to another quarter which he may have calculated as being

[12] RUTT, *op. cit.*, Vol. 1, pp. 198, 255. Trudaine de Montigny was intimately associated with the Abbé Morellet, whom Fäy (FRANKLIN, p. 353, **1927**) described as being "expert in avoiding God." Lavoisier left in his papers a vigorous condemnation of the Catholic clergy, whom he blamed for the backward condition of popular education. See GUILLAUME, J., "Revue historique de la Révolution Française," **52,** 403 (1907). Priestley also encountered this oppressive influence. "At present they are miserably hampered by the *censeurs* of the press. The person who has translated my treatise on Air could not obtain leave to insert that paragraph in the preface in which I speak of the consequence of the spread of knowledge with respect to religion." (RUTT, *op. cit.*, Vol. 1, p. 256).

[13] PRIESTLEY, J., "The doctrine of phlogiston established," **1803,** p. 88.

[14] Possibly the best exposition is the neutral account and interpretation by MELDRUM, A. N., "The eighteenth century revolution in science. The first phase," Longmans, Green and Co., Ltd., **1929.** See also HARTOG, P., *Proc. Roy. Inst.*, **26,** 395 (1931).

[15] FOSTER, M., "History of physiology," Cambridge, **1901,** p. 245.

[16] MINNEGERODE, M., "Jefferson, friend of France," **1928,** p. 78. E. E. Genêt (1763–1834) in 1782 became connected with the Académie by virtue of appointment as correspondent to the honorary member, the Duc de La Rochefoucauld.

[17] LAVOISIER, "Œuvres," **2,** p. 130.

a strategic one for indirectly bringing the matter to Lavoisier's attention. On December 31, 1775, in a letter to Thomas Henry, who brought out a translation of Lavoisier's *Opuscules* in 1776, Priestley wrote, "He is an *Intendant of the Finances* and has much public business, but finds time for various philosophical pursuits for which he is exceedingly well qualified. He ought to have acknowledged that my giving him an account of the air I had got from mercurius calcinatus, and buying a quantity of M. Cadet while I was at Paris, led him to try what air it yielded, which he did presently after I left. I have, however, barely hinted at this in my second volume."[18]

Priestley tired of Paris and, leaving Lord Shelburne behind, arrived in London on November 2. He had spent many of his evenings with J. H. Magellan, who accompanied him to England, "and made the journey very pleasing to me, he being used to the country, the language, and the manners of it, which I was not. He had seen much of the world and his conversation during our journey was particularly interesting to me. Indeed in London, both before and after this time, I always found him very friendly, especially in everything that related to my philosophical pursuits."[19]

Priestley's traveling companion, Joao Hyazinthe de Magellan (alias Magalhaens or Magelhaens) was one of the most interesting figures of the scientific world of the time. A descendant of the great navigator, he was born (1722) in Lisbon, became an Augustinian monk, decided to devote himself to science, and seeking a more propitious environment, he emigrated to England in 1764, where he embraced Protestantism. Because of his outstanding linguistic ability he frequently was engaged as tutor to wealthy young men making tours of the Continent. He thus became personally acquainted with the leading scientists of all Europe and maintained an active correspondence with many of them. These private communications, which gave him an early knowledge of new discoveries, led him to realize the potential value of an international clearing house for scientific information, but his efforts to establish such a medium did not bear fruit. However, he did act as London agent for scientists in the English provinces and abroad and Lavoisier, whom he knew intimately, was kept abreast of the latest discoveries of Priestley, Cavendish, etc., by Magellan, who sent him the English publications which Madame Lavoisier then translated for her husband. Priestley, after his removal from London, also used Magellan's services, and in 1790 wrote, "Since Mr. Magellan's death (February 7, 1790) I am at a loss for a person to take up and transmit to me the volume of the Philosophical Transactions." Magellan published extensively in several fields, particularly on physical and astronomical equipment. His chemical works included a treatise on fire and descriptions of eudiometers and apparatus for making mineral water. The Academies of France, Berlin, St. Petersburg named him correspondent, but none of these was honored by him in his will, as was the American Philosophical Society at Philadelphia, to which he left 200 guineas to establish the Magellanic Prize, a gold plaque, awarded from time to time for the best discovery or invention relating to navigation, astronomy, or natural philosophy.[20]

Although Lavoisier was ten years younger than Trudaine de Montigny, they had so much in common that their intimate friendship was inevitable as soon as they were associated with the same groups. Reared in families of cultured outlook, whose financial standing made an excellent education possible, the young men were taught not only the humanities but also the sciences. On May 2, 1868, Lavoisier's father bought his son a third interest in a share of the Ferme Générale; on May 20, the young scientist was elected to the Académie.[21] In both these bodies he was continually thrown into contact with Trudaine de Montigny, whose intendancy involved supervision of certain activities of the tax-gathering corporation. The young men found that their views, political and economic, were much the same; they both strove for freedom of trade, for a more equitable distribution of the tax burden, and for cheaper methods of collecting the taxes. They admired Turgot, with whom Trudaine was so intimately allied that he often gave the progressive statesman sound and forceful advice on the most expedient methods of furthering reforms.[22] The leaders of this progressive group sometimes gathered at the château at Montigny to discuss their plans, but in the history of chemistry, the chief interest attached to this mansion arose from the fact that its laboratory had as its guest not only Priestley, but also Lavoisier, who worked there from time to time.

Most of Lavoisier's laboratory journals for the period 1772–88 have been preserved. Thirteen volumes are at Paris in the archives of the Académie while one, which should constitute Volume 2 of the Académie's series, is at Perpignan.[23] Trudaine's name appears at intervals and the entries show the progress in the scientific association of the two friends. June 28, 1773,

[18] HENRY, WM., *Rept. Brit. Assoc. Adv. Sci.*, **1831**, (2nd ed.), p. 71.

[19] RUTT, *op. cit.*, Vol. 1, p. 198; Vol. 2, p. 93.

[20] Lavoisier, Magellan, and Trudaine de Montigny were all involved in the development of equipment for distilling sea water on shipboard. This matter was in progress in 1774 and doubtless was one of the reasons for Magellan's presence in Paris at the time of Priestley's visit. See DUMAS, J. B., "Œuvres de Lavoisier," Vol. 4, p. 75; GRIMAUX, E., *op. cit.*, p. 137; SPETER, M., *Chem.-Ztg.*, **32**, 3, 654 (1903); *Chem. Apparatur*, **1**, 86 (1914); **16**, 59, 198 (1929). Lavoisier was made a member of the American Philosophical Society on January 28, 1775, and was a member to his death. He contributed nothing to its *Transactions*.

[21] For an excellent review and appraisal of Lavoisier's early work in science see MELDRUM, A. N., *Isis*, **19**, 330 (1933); *ibid.*, **20**, 396 (1934).

[22] Condorcet, influential both in the Académie and in political circles, liked neither Lavoisier nor Trudaine de Montigny. He criticised their ideas and actions severely to Turgot. HENRY, C., "Correspondance inédite de Condorcet et de Turgot," **1883**. See Figure 5.

[23] Annotated summaries of the contents of these laboratory day books are given by BERTHELOT, M., "La révolution chimique (1890)," *Comptes rend.*, **135**, 549 (1902).

"I have carried out a metallic reduction for M. Trudaine." . . . Sept. 24, Lavoisier repeated experiments designed to verify Black's findings in presence of Trudaine and others. . . . November, Lavoisier went over his work on the liberation of ammonia from sal ammoniac by calcium carbonate, "because of doubts raised in my mind by M. de Trudaine."

During the autumn of 1773 Lavoisier was writing his *Opuscules*, and in December he submitted the manuscript to the Académie to secure its imprimature. A committee, which included Trudaine, handed in a long laudatory report and the *Opuscules* appeared in January, 1774, with a dedication to Trudaine.[24] The long analysis of this work, prepared for the Histoire de l'Académie, though unsigned, was written by Lavoisier himself, and Meldrum asserted that the committee report was likewise the work of the author of the *Opuscules;* "No one else could have written either the one or the other."[25]

Within a few days of Priestley's departure from Paris, Lavoisier, doubtless incited by personal contact with the English authority on pneumatic chemistry, began repeating Priestley's experiments on gases. He, too, left Paris and on October 28, 1774, was busy in the laboratory at Montigny. Aided by his host, he investigated in turn marine acid air, the formation of nitrogen oxides by sparking atmospheric air, the air obtained from the detonation of niter, etc. Not until sometime in November did they prepare the gas from mercury calx.[26]

This delay effectually disposes of the belief that Lavoisier, after Priestley's disclosure, had, so to speak, rushed from the table to the laboratory to get into his own hands the key to the solution of the difficulties that were then enveloping his notions of combustion and calcination. In fact, he attached so little importance to this experiment that he omitted all mention of it in his laboratory journal, and only in a footnote to his paper of April 26, 1775, "On the nature of the principle that unites with metals during their calcination and that increases their weight," does he record that "the experiments on mercury precipitate *per se* were first tried in November, 1774, and later carried out with all precautions and necessary care in the laboratory at Montigny jointly with M. Trudaine, on February 28, March 1 and 2 of this year; finally they have been repeated on the 31st of March in the presence of M. le Duc de La Rochefoucauld, MM. Trudaine, de Montigny, Macquer, and Cadet."

[24] The dedication appears only in the first edition; it was deleted in the so-called second edition (really a reprinting) because in 1801 both the principals were long since dead.

[25] MELDRUM, *op. cit.*, p. 17; GRIMAUX, "Œuvres de Lavoisier," Vol. 5, **1892**, p. 320.

[26] In order to settle a dispute between Baumé and Cadet, the Académie, on September 3, 1774, ordered Brisson, Lavoisier, and Sage to determine whether mercury could be produced from mercury calx by the application of heat alone. The report, written by Sage and handed in on November 19, stated that 91–92% of mercury could be so obtained; the committee did not concern itself with the missing 8%. See JÖRGENSEN, ORTWED, SPETER, *Ahrens Sammlung*, **14**, 134 (1914).

FIGURE 5.—BUST OF CONDORCET BY HOUDON

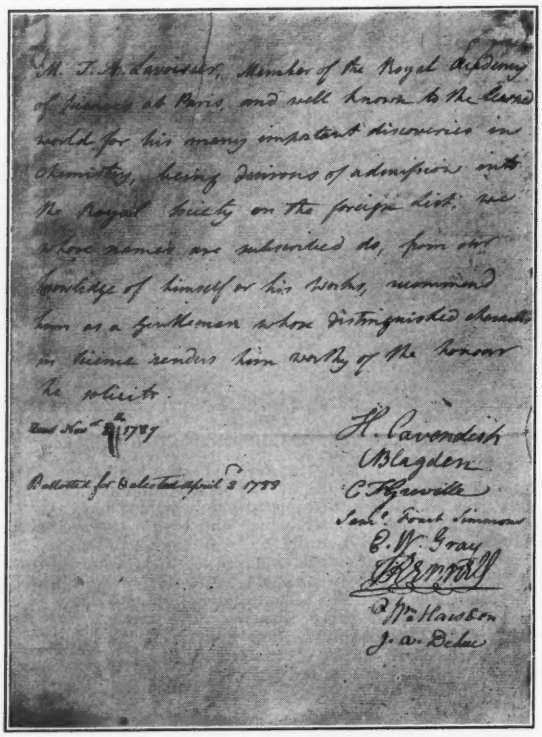
This terra cotta bust, transferred to the Louvre in 1896 from the Conservatoire des Arts et Métiers, and a similar one in marble sent to Philadelphia at the beginning of the 19th century, have been widely copied and represented as being Lavoisier. This has been the case with respect to the bust in the library of the Académie, and also as to the bronze statue of Lavoisier [see THIS JOURNAL, **11**, 211(1934)] erected behind the Madeleine, in which this Houdon bust was used as a model by Barrias. Recent studies have proved that the likeness is not Lavoisier, but Condorcet. See SMOUSE, "Revue de l'art ancien et moderne," April, 1914, p. 290; LEMAY, *Le Courrier Médical*, March, 1934, p. 183.

Priestley, on his return to England, began to study the new gas and by November 19 he knew that his first suspicion that it was nitrous oxide was incorrect. He then abandoned this line of inquiry and turned to experiments provoked by the single trial at Trudaine's laboratory, and eventually he isolated sulfur dioxide. Not until March 1, 1775, did he resume his work on oxygen, the delay being due perhaps to the fact "that chemistry was really little more than a hobby to him, theology was his life work. His chemical work was a series of experiments whose charm for him consisted in the actual manipulation and not so much in the scientific results achieved. A pretty experiment was often repeated many times, while an important discovery, such as that of oxygen, would be neglected for months."[27] In his "Experiments and Observations," he arranged his work, to a large extent, in chronological order, a method necessitated by the fact that each volume was generally published as soon as sufficient

[27] PEACOCK, D., "Joseph Priestley," Society for Promoting Christian Knowledge, London, **1919**, p. 56.

results had accumulated. The first volume had been so well received that a reprinting was soon required, and thus encouraged he wrote, January 10, 1775, "A new edition of my treatise on Air is in the press, and I have made so many additions to my Observations that I propose to publish a Supplement to that work before I leave London (*i. e.*, for Calne, Shelburne's summer residence). But the more I do the more I see is to be done."

Resuming work on the gas from mercury calx, by


M. L. A. Lavoisier, Member of the Royal Academy of Sciences at Paris, and well known to the Learned world for his many important discoveries in Chemistry, being desirous of admission into the Royal Society on the foreign list, we whose names are subscribed do, from our knowledge of himself or his works, recommend him as a Gentleman whose distinguished abilities in Science renders him worthy of the honour he solicits.

Read Nov. 27th 1787

H. Cavendish
Blagden
C. Greville
Sol. Fr. Simmons
P. W. Gray
W. Watson
J. A. Deluc

Balloted for & elected April 3 1788

FIGURE 6.—LAVOISIER'S APPLICATION FOR ADMISSION TO THE ROYAL SOCIETY

Note that Lavoisier's initials are transposed, an error that also occurs in the minutes of the Society in several places. It was the custom to display these applications publicly on the walls of the library. Priestley was living in Birmingham at this time, which may explain why he was not one of the signers of this application.

March 1, 1775, he knew that it was a new kind of air and for Priestley himself this is clearly the date of the discovery of oxygen. The first public announcement was made on March 23, when his letter of March 15, telling of what he had done, was read by its recipient, Sir John Pringle, to the Royal Society. Later letters (Rev. Price, April 1, read April 6; May 23 to Pringle, read May 25) kept the London scientists apprised of the developments.[28] Letters to even his theological colleagues testify to the dominant interest the new gas occupied in his mind during these pregnant months. To Rev. Lindsey, on March 25, he wrote, "I have got a cheap method of making my new air in large quantities, but cannot pursue my experiments as I wish on account of my boils, otherwise I have very many promising things in view." To the Rev. Turner, April 6, "At present I am chiefly intent on my experiments, and I was never more successful than I have been of late. I now do not intend to make a supplement to my late treatise on Air, but to defer publication 'til the next winter when in all probability, I shall have materials for another volume. I have now discovered an air five or six times as good as common air. I got it first from *mercurius calcinatus per se*, red lead, etc., and now, from many substances as quick lime (and others that contain little phlogiston) and spirit of nitre, and by a train of experiments demonstrate that the basis of our atmosphere is spirit of nitre. Nothing I ever did has surprised me more, or is more satisfactory."[29]

Priestley probably read Lavoisier's paper of April 26 in the May issue of Rozier's journal[30] and found there no mention of what he had told Lavoisier the previous October. As he was then composing the second volume of his "Experiments and Observations" (it went to the printer on July 7), he used this opportunity to advise Lavoisier as to the proprieties of properly acknowledging what we owe to others. "I am not conscious to myself of having concealed the least hint that was suggested to me by any person whatsoever or any kind of assistance that has been given me." (p. *ix.*) . . . "I have hitherto made the most early publication of my observations and have concealed from no person whatever anything that has occurred to me; and though this conduct has exposed me to some inconvenience, I am not yet discouraged, but whoever may avail themselves of it, I shall, for some time longer at least, and I hope through life, persist in the same habit of the most open and unreserved communication public and private." (p. *xxvii.*) Noting the weakness of Lavoisier's findings in comparison with his own, he felt safe from serious competition from his "excellent fellow labourer in these inquiries." "When he sees this volume of mine, he shall, I doubt not, be convinced of the imperfection of his theory and of the mistake which he has been led into by means of it. As a concurrence of unforeseen and undesigned circumstances has favoured me in this inquiry, a like happy concurrence may favour Mr. Lavoisier in another, and, as in this case, truth has been the means of leading him into error, error may in its turn lead him into truth." And then this final thrust, "It is pleasant when we can be equally amused with our own mistakes

[28] CAVEN, R. AND HARTOG, P., *Nature*, **132**, 25 (1933). For the text of Priestley's letters see *Phil. Trans.*, **65**, 384 (1775).

[29] RUTT, *op. cit.*, Vol. 1, p. 267. His method was to moisten the quick lime with nitric acid, dry the mixture, and then heat it. The mixture of oxygen and nitrogen peroxide was passed through water.

[30] LAVOISIER, *Observations sur le physique*, **5**, 429 (1775). This should not be confused with the revised version ("Œuvres," **2**, 122), read at the Académie, August 8, 1778, and published in 1778 in the Mémoires de l'Académie for 1775.

and those of others. I have voluntarily given others many opportunities of amusing themselves with mine when it was entirely within my power to have concealed them. But I was determined to show how little *mystery* there really is in the business of experimental philosophy, and how with little *sagacity* or even *design*, discoveries (which some people are pleased to consider as great and wonderful things) have been made." (p. 322.) Priestley was poking fun at Lavoisier, whom he probably considered a tyro in the business of working with gases, but the world knows the eventual outcome of this competition. "There are ways in which Priestley surpassed Lavoisier easily. Priestley produced new gases in profusion, he was expert in handling a gas and in discovering its properties. But there was no ruling purpose behind his work and there was no austerity in his thinking. Ultimately Lavoisier must surpass Priestley. He was in earnest about what Priestley passed over lightly and amiably. His work was inspired by a great motive and was controlled by a principle. He had striven to bring about a revolution in science and had been groping in the dark. . . . Once he understood all that Priestley could tell him about oxygen, he could see his way to the revolution in science of which he had dreamt."[31]

Priestley never saw either of the Frenchmen again. No other letters between him and Trudaine de Montigny have come to light, though Priestley must have written to thank him for sending the sheets to Gibelin. Lavoisier and Trudaine continued their close friendship; a stay at Montigny became an annual event and Lavoisier's day books record work done at Trudaine's laboratory in October, 1775 and 1776. Trudaine withdrew from public service as much as he could; his efforts on behalf of the lower classes were misunderstood and his motives were impugned. Despondency brought on ill health, he failed rapidly, and on August 7, 1777, he died in his carriage while inspecting his estate. His remains lie in the church at Montigny.

Both Lavoisier and Priestley were inveterate letter writers, but not to each other. Apparently the only letter extant is one of June 2, 1792, in which Priestley asked Lavoisier to receive the Rev. David Jones, "lecturer in chemistry at the New College in Hackney, in which employment I now succeed him, and who is to be my successor at Birmingham. You will find him to be equally modest and sensible, and as a philosopher more inclined, I believe, to your system than to mine, but open, as we ought all to be, to correction as new facts present themselves to us. The late riots have interrupted my experiments near a whole year, but I am now refitting my apparatus and about to resume my usual pursuits, and I shall not fail to give due attention to what you may advance in reply to my last memoir on the subject, a copy of which I send you, and for this purpose I shall be glad to be informed concerning them. Mr. Jones will convey your sentiments to me." The sequel to this note is hinted at in Priestley's letter of October 22 to the chemist and botanist, William Withering, "I am surprised at the confidence with which the French chemists write, but I cannot yet learn what they have to object to in my last Paper in the Philosophical Transactions. A friend at Paris, at my request applied to M. Lavoisier and others but he got no satisfactory answer . . ."[32]

Priestley's laboratory at Birmingham was destroyed by a mob on July 14, 1791. The chemists of Paris, shocked at this outrage, which indirectly had its genesis in the political turmoil of France, drew up a testimonial in praise of Priestley's accomplishments and declared their intention to refit his laboratory, "this Temple, which ignorance, barbarism, and superstition have dared to profane. What greater service could we render the sciences than to place in your hands the instruments necessary to pursue them?" The unsigned draft of this flowery document bears corrections in Lavoisier's handwriting, and Loewenfeld, the owner of this manuscript, said, "It is thus evident that Lavoisier, who had many a scientific rencontre with his English contemporary showed himself a staunch friend in the hour of need."[33] It is probable that this letter

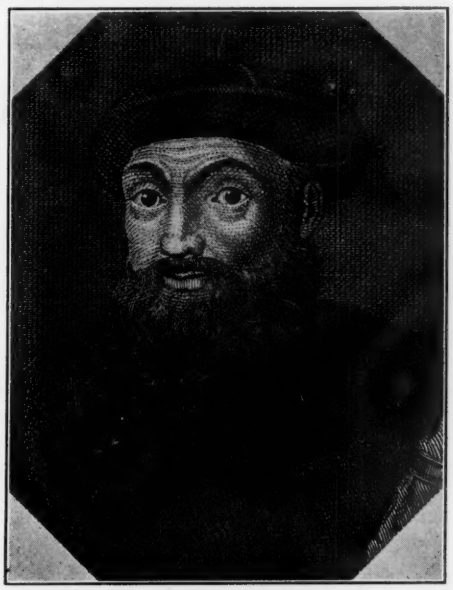


FIGURE 7.—H. MAGALHAENS

was never sent or received as there is no reference to it in any of Priestley's or Lavoisier's papers or correspondence.

Priestley was on his way to America when Lavoisier was guillotined on May 8, 1794, and it is not known

[31] MELDRUM, *op. cit.*, p. 60.

[32] BOLTON, H. C., "Scientific correspondence of Joseph Priestley," **1892**, pp. 129, 131.

[33] LOEWENFELD, K., *Memoirs and Proceedings of the Manchester Literary and Philosophical Society*, **57**, part 3, p. 47 (1913).

when the news of this judicial murder reached him. Not a word concerning his reaction to this calamity is recorded, truly remarkable since he otherwise was so voluble. But assuredly his silence was not dictated by fear, jealousy, or indifference, sentiments that have been ascribed to Lavoisier's scientific associates in Paris, who though in positions of influence stood by and raised no voice in protest or solicitation.[34] Lavoisier inspired respect but not affection, and his close friendship with Trudaine de Montigny is all the more remarkable for this reason. Furthermore, it formed a chapter in his early manhood, before he attained eminence in the scientific and financial world, but whether his success would have interrupted or terminated the intimacy is pure speculation; but at least we know that he seems to have not entered into a similar relationship with anyone else.

Trudaine's sons, Trudaine de Montigny and Trudaine de la Sablière, apparently inherited none of their father's interest in science. They cultivated arts and letters and gathered around them a circle of sympathetic élite, including the artist, David, to whom we owe the only authentic portrait of Lavoisier.[35] They, like Lavoisier, were members of the Club of '89, whose rolls included the enlightened aristocratic proponents of the revolutionary movement. Caught in the net of the Terror, the brothers, through friends, appealed to David, a member of the powerful Committee of General Security. His reply was a threat to have the solicitors imprisoned. Robespierre was irritated by repeated efforts in their behalf and ordered them before the Tribunal. The sentence was pronounced by Coffinhal who had presided at Lavoisier's trial and into whose mouth has been put the infamous but probably apocryphal phrase, "The Republic has no need of scientists. Let justice take its course."[36] The Trudaines were guillotined on July 26, 1794, only one day before the Terror ended. They left no children. The widow of the elder brother had the laboratory at Montigny dismantled and presented the equipment used by her father-in-law and his guests to the Abbé Sieyes. The château was torn down in 1852.

[34] ROBISON, J., "Black's lectures on the elements of chemistry," Vol. 2, **1803**, p. 220; GRIMAUX, E., *op. cit.*, p. 309; SPETER, M., *Z. angew. Chem.*, **40**, 1235 (1927); *idem*, *Unsere Welt*, **21**, 355 (1929).

[35] This masterpiece was purchased in 1925 by J. D. Rockefeller, Jr., from the descendants of Mme. Lavoisier, and to the sorrow of the French scientists was taken from France. The well-known portrait of the Lavoisiers now adorns the library of the Rockefeller Institute.

[36] GUILLAUME, J., "Revolution française," **38**, 385 (1900).

The USE *of* CHEMICAL HISTORY *in the* HIGH SCHOOL

GRETA OPPE

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IN THE JOURNAL OF CHEMICAL EDUCATION, **12**, 367–69 (August, 1935) there appeared a study, "Historical Materials in High-school Chemistry Texts." In their conclusions, the authors, J. O. Frank and Lester Lundsted of State Teachers' College, Oshkosh, Wisconsin, declared that there is no agreement among textbook authors as to what historical materials should be given nor as to how they should be presented. One might add that there is no agreement among teachers either and therefore the significance or importance of historical chemistry is often overlooked.

The American Chemical Society has recently celebrated the tercentenary of American chemical industries. As a teacher of chemistry, I would like my pupils to appreciate that. I want them to know that from 1833 to 1933 we experienced a century of progress in science, and that since 1914 our chemical industries have grown tremendously. By creating such an historical background, I believe I can make them see the real spirit of chemistry and the necessity to take an interest "in these sacred dwellings called laboratories."

I therefore offer this lesson unit in historical chemistry because the culminating activities in our high school have been so far beyond our expectations that I believe the materials and suggestions may be of value to others as to what and how historical materials may be capitalized.

Our major objectives for the unit were:

1. To develop a knowledge of the past and an appreciation of these early attempts at scientific thinking.
2. To acquaint boys and girls with the men and women who have influenced the field of science from its beginning to the extent that they may become increasingly aware of the human side of chemistry, and develop a sympathetic attitude toward those who are engaged in the pursuit of science.
3. To show that out of the past has come a science which affects the present and offers to every citizen a method of treating intelligently problems which affect the welfare of our country and of all peoples.

You may think of several ways of approaching the subject. We introduced the subject by a very simple, direct question: why should we study about early men?

Woodrow Wilson at the Princeton sesquicentennial

said, "The world's memory must be kept alive or we shall never see an end of its old mistakes." Thus we answered the question by saying that we profit by the mistakes of others; that human history is a continuous development; all have borrowed, each must give; that we owe much to the people who lived long ago.

Our first activity was to trace the origin of the word chemistry, and out of its origin there grew the following suggested outline of content.

I. Chemistry in ancient times.
Elements known to the ancient world. MARY ELVIRA WEEKS, "The discovery of the elements," pp. 2–8.

II. The period of alchemy.
Who were the alchemists? Where and when did they flourish? Meaning of the term alchemy. What two lines of endeavor did they follow? Elements known to the alchemists (pp. 9–18, "The discovery of the elements"). Read Chaucer's "Canon's Yeoman's Tale" and follow it with a modern tale of alchemy, the story of Franz Tausend, "gold-maker," *Literary Digest* (May 9, 1931). Discuss the present attitude of scientists toward the work of alchemy.

III. The phlogistic period.
Meaning of phlogiston. The story of Priestley. Reference: "Priestley number," J. CHEM. EDUC., **4** (Feb., 1927).

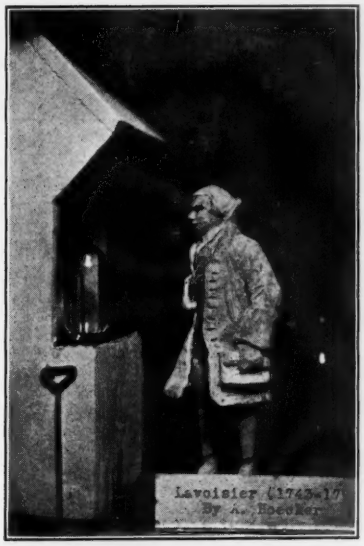
IV. The discovery of oxygen, the overthrow of the phlogistic period, and the beginning of modern chemistry. Read Chap. 4, "Discovery of the elements." Class report: Antoine Lavoisier.

V. Chemistry today—its work in the world.

VI. Chemistry in America.
Readings:
BRANEGAN, JAMES A., "Chemistry and science in prehistoric America," J. CHEM. EDUC., **2**, 588 (July, 1925).
NEWELL, LYMAN C., "Colonial chemistry—I. New England," *ibid.*, **2**, 161–4 (Mar., 1925).
LAMB, ARTHUR B., "A century of progress in chemistry, 1833–1933," *Science*, **78** (Oct. 27, 1933).
BROWNE, C. A., "The three-hundredth anniversary of chemical industries in America," *Ind. Eng. Chem.*, **12**, 427 (Dec. 10, 1934).
Boston Evening Transcript, Tercentenary Supplement, April 22, 1935, "American Chemical Industries, 1635–1935."
Little research studies for the student:
John Winthrop, Jr., alchemist, founder of American chemical industries.
George Washington and science.
Abraham Lincoln, inventor.
Herbert Hoover, scientist.
Irving Langmuir (and any others, depending upon time available).
Elements discovered by Americans:
HOPKINS, B. S., "Illinium, a new element," *Science*, **63**, 757 (1926).
"Latest found elements named after Virginia and Alabama," ANON., *Sci. News Letter*, **21**, 565 (Feb. 6, 1932).

There are several ways of acquainting oneself with the events and personalities of chemical history. The usual method is collateral reading, a method which should not be discarded but which is so often overworked. This unit offers an excellent opportunity for the study and collection of pictures. One should make plentiful use of display boards. Newspapers should be carefully scrutinized, and magazines will often afford valuable information for the student of historical chemistry. During centennials and bicentennials we have filed much valuable material.

Pictorially portrayed chemistry leaves a lasting impression. A new way to portray the history of chemistry is by a "modeled" form of three-dimensional pictures or dioramas, so popular and so dramatic in appeal at the Century of Progress in Chicago. The dioramas pictured here were made by chemistry students of the Ball High School at Galveston, Texas.



LAVOISIER, "THE FATHER OF CHEMISTRY"
(Modeled out of soap)

GOODYEAR DISCOVERING VULCANIZATION
(Carved from wood)

In presenting the lives of our scientists, see to it that the boy life is included as well as the professional life, for the personal element is needed to stimulate interest.

In evaluating this unit you may well ask at least two questions; namely, did these students evidence any permanent interest, and did they acquire any ability in searching for source material? This unit came into

AN ALCHEMIST'S LABORATORY
(Modeled out of plaster of Paris)

being and continued only because of the abundance of material brought in by teacher and pupils and the student-teacher practice of filing clippings from newspapers and magazines. Every year letters are received from ex-students which contain pictures and articles with a statement, "I found this one in——"; and as if to emphasize the truth of that statement made by the author, the postman brought one just as this article was being concluded.

Time is one element that always enters into our teaching. It is not necessary to teach historical chemistry all at one time. Historical beginnings may well be placed at the beginning of a chemistry course, while American chemistry and chemistry today make a fitting close, especially if we can make our students see that if the scientific method has done so much for chemistry in the past, might not its critical attitude of examining things and its service be an important reason for studying chemistry today? I also believe that the time has now come for us to capitalize the historical aspect of American chemistry in our textbooks and in our teaching to show our pupils that chemistry has no small influence on the lives of our American people.

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JAFFE, BERNARD, "Crucibles, the lives of great chemists," Simon and Schuster, New York City, **1930.**

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ARRHENIUS, S. A., "Chemistry in modern life," D. Van Nostrand Co., New York City, **1925.**

JAFFE, BERNARD, "New world of chemistry," Silver, Burdett and Co., New York City, **1935.**

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HALE, HARRISON, "American chemistry," D. Van Nostrand Co., New York City, **1921.**

JOURNAL OF CHEMICAL EDUCATION, Easton, Pa.

Science, a weekly journal devoted to the advancement of science, Lancaster, Pa.

Industrial and Engineering Chemistry, New York City.

AN ADJUSTABLE SUPPORT AND STAND FOR BUNSEN BURNERS

I. A. BALINKIN

University of Cincinnati, Cincinnati, Ohio

A LIMITED space on the laboratory table called for a simple device that could be directly attached to a Bunsen burner to support a small crucible at variable distances from the flame. Such an adjustable ring support is shown in Figure 1 (*a*). It consists of a split piece of brass, *A*, a supporting-rod, *B*, and a ring, *C*. The change in height can be effected by sliding the piece, *A*, along the length of the Bunsen burner's tube, or by moving the supporting-rod, *B*, up or down. This double adjustment allows the ring, *C*, to be brought close to or as high as six inches from the mouth of the burner. The ring is four inches in diameter and can accommodate a variety of vessels or objects to be heated.

The same device has also been conveniently employed in the student laboratory as an adjustable stand for a Bunsen burner as shown in Figure 1 (*b*). Although the total rise is only four inches, it is sufficient to bring the flame of the burner to the proper level of a student spectroscope for a study of flame spectra.

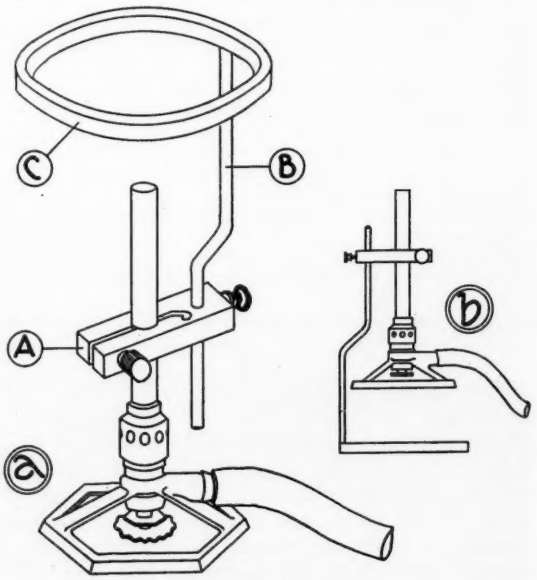


FIGURE 1

CRYSTAL CHEMISTRY

*I. A GRAPHIC CLASSIFICATION OF BINARY SYSTEMS**,†

CHARLES W. STILLWELL

Dennison Manufacturing Co., Framingham, Massachusetts

IN AN earlier series (*1a, b, c*), the fundamentals of crystal chemistry were developed as they might be used in the elementary course.

For the elementary class, the time necessary to present a complete picture of crystal chemistry is not available. The discussion must be limited to the broad concepts which govern the structures and properties of those types of compound most familiar to the elementary student. Only a few suggestive sketches of what is to be expected can be offered.

It is of considerable interest to extend the application of the fundamental concepts of crystal chemistry in greater detail, and in the pages which follow they will be discussed as they determine the structures and properties of the binary compounds.

A GRAPHIC CLASSIFICATION OF BINARY SYSTEMS

A classification of the binary systems is illustrated in the accompanying chart. Were this chart merely a collection of crystal structure data, its compilation would hardly be justified. Such information may be found in more convenient form elsewhere. The value of the chart lies in the arrangement of crystal structure and other data, to illustrate the influence of the properties of ions and atoms upon the structure and properties of the crystals formed by compounds of these ions and atoms. To the extent to which this has been accomplished, the chart is not merely a collection of useful facts, but illustrates the development, from experimental data, of the most important principles of crystal chemistry as applied to binary systems.

The elements are listed in the same order away from the origin, both vertically and horizontally; thus a space is provided for each possible binary system. Nearest to the origin are those elements with the typical, close-packed, metallic structures—the true metals. They are close-packed, hexagonal, face-centered cubic and body-centered cubic, and are arranged in the order of their groups in the periodic table. Following these are the elements with abnormal metallic structures (zinc, cadmium, mercury, aluminum, gallium, indium, thallium, lead, tin), still predominantly metallic in structure and properties. Farthest to the right (and nearest the top) are the non-metallic, electronegative elements.

With this arrangement of coördinates, the binary systems group themselves naturally into three large areas.

1. *The alloys*, the majority of which are systems of two electropositive elements, in zones I, II, III, IV, V (VI, VII). These are discussed very briefly in the present paper.
2. *The ionic and atomic "valence" compounds*, formed by the union of an electropositive with an electronegative element, in zones VI, VII, and VIII.
3. *The molecular compounds*, generally of two electronegative elements, in zone (VIII), IX.

Recently Grimm (*2*) has proposed a classification of binary compounds, differing from the chart here presented in that the elements are arranged along the axes according to their atomic numbers, rather than in order of decreasing "metallicity." The prevalent bond type has been recorded for each binary system. For purposes of classification and generalization concerning the influence of ionic and atomic properties upon the structures of binary compounds, his chart is very confusing, since systems in which a given bond type prevails are widely scattered over the chart in many small areas.

Evidently it is difficult to draw sharp lines of demarcation between the three general classes of binary systems as listed above. The line between the alloys and the large group of ionic and atomic compounds has been drawn arbitrarily at germanium, although binary compounds of metals with more electronegative elements (like silicon, arsenic, antimony, bismuth, selenium, tellurium) have certain alloy-like properties. Their inclusion would not necessitate any new classification, however, but would merely widen zone V. Zone VI, the interstitial compounds of the transition elements with hydrogen, boron, and nitrogen; and zone VII, including ionic and atomic compounds with certain metallic properties, are plainly intermediate zones. Zone IX marks the region of molecular compounds of two electronegative elements, but there are also molecular crystals to be found in zone VIII, particularly compounds with the general formula AX_4.

THE ALLOYS

The alloy region of the chart has been designed to show, as far as possible, the conditions under which two metals in the solid state will be completely miscible, mutually soluble, partly soluble, immiscible; or when they may be expected to form intermetallic compounds or superstructures. Predictions of these tendencies must, necessarily, be very general. When these characteristics of each alloy have been recorded, four

* First of six parts.

† Presented before the Division of Physical and Inorganic Chemistry at the eighty-ninth meeting of the American Chemical Society, April 26, 1935.

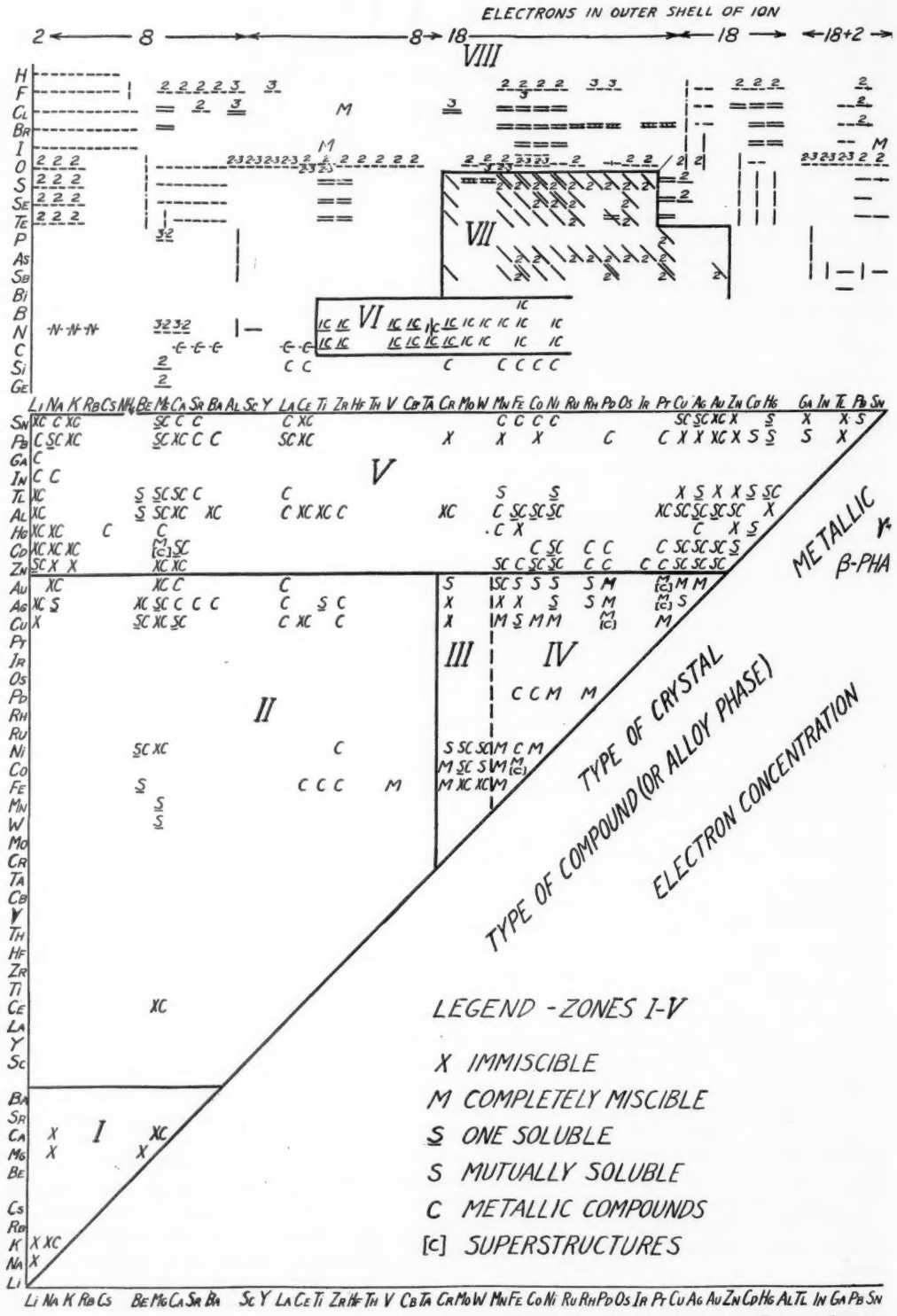
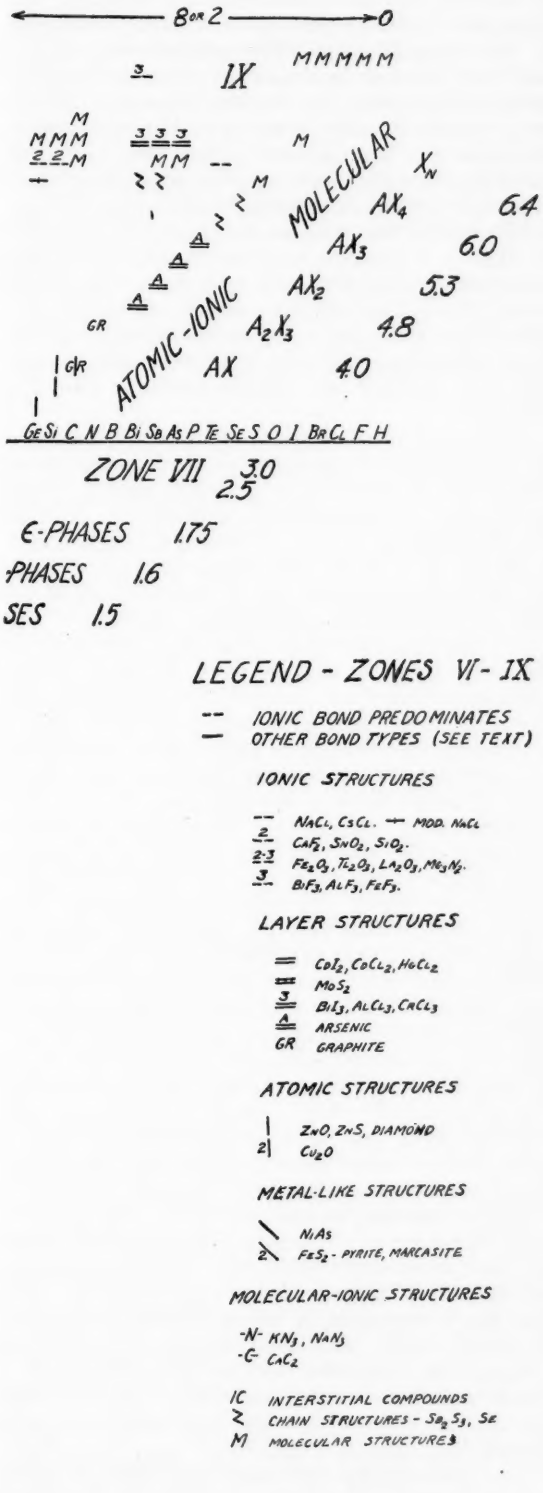


FIGURE 1.—CLASSIFICATION OF BINARY SYSTEMS



rather well-defined zones—areas in which all the systems possess similar properties—are apparent.

In zone I, including the alkali and alkaline earth metals, the metal pairs are immiscible, but may form compounds. Zone III includes the transition elements, among which all the completely miscible pairs (except Mg-Cd) are found. Within this is zone IV, in which complete miscibility predominates. Many of the superstructures are also found in zone IV, but intermetallic compounds are almost unknown. Zone II, including the remaining binary alloys of the true metals, is evidently intermediate in nature. Compound formation is the exception, rather than the rule, among most of the true metal pairs.

Most of zone V includes alloys of a true metal with a distorted or abnormal metal,* and it is apparent that under these conditions intermetallic compounds are nearly always formed. A great deal might be said of this natural zoning of the alloys according to their tendency to form solid solutions or compounds, but only a brief statement can be made of the factors which are generally conceded to influence solid solubility and compound formation. The relation of these factors to the zoning then becomes obvious.

The more easily a solvent metal lattice can be distorted, the greater its dissolving power. The less the distorting influence of the solute metal, the greater its solubility. In general, complete solid miscibility of two metals is favored when both metals are:

1. true metals; not all true metals are miscible, but true metals and abnormal metals are never miscible (except Mg-Cd);
2. face-centered cubic, or polymorphous;
3. of equal, or nearly equal radii (within 15%);
4. of relatively small atomic radii;
5. equi-valent.

As the metals in question deviate from these requirements, their mutual solubility will decrease and the tendency toward compound formation may increase.

Hume-Rothery has shown (*3*) that for the binary alloys of copper and silver with almost all the abnormal metals, the relative atomic radii are most important in their influence upon solid solubility. If the sizes are compatible (within 15% of each other), then the chances of solid solution or compound formation depend upon the relative valences of solvent and solute metals. The so-called electron concentration† limits the extent of solid solubility. When it equals or exceeds about 1.5, intermetallic compounds will be formed (see Table 1).

Applying these general observations to the chart, it may be seen that:

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* The true metals are close-packed structures, hexagonal or cubic, or body-centered cubic. In the abnormal metals (listed in the preceding text), the atoms are not in closest packing, but the crystal structure is characterized by a high coördination number, typical of the metallic state. See C. W. STILLWELL, J. CHEM. EDUC., **10**, 590 (1933); J. C. FERNELIUS AND R. F. ROBEY, *ibid.*, **12**, 55–68 (1935).

† The number of valence electrons per atom.

1. the zone I alloys tend to be immiscible because they differ greatly in size and are usually body-centered cubic—not easily distorted;
2. the eighth group transition elements tend to be miscible because they are about the same size, are small and are face-centered cubic—easily distorted;
3. a true metal and an abnormal metal tend to be only partly miscible because they may differ in size, but particularly because the abnormal metal will not tolerate much distortion. These pairs tend to form intermetallic compounds as the addition of the di-, tri-, or tetravalent metal increases the electron concentration of the system.

THE IONIC AND ATOMIC COMPOUNDS

These are the familiar binary "valence" compounds. Four properties of each are recorded on the chart:

1. the electronic structure of the ions;
2. the crystal structure of the compound;
3. the type of bond in the crystal;
4. the stoichiometric formula of the compound (shown indirectly).

It is possible, therefore, to observe the effect of electronic structure (and related polarization properties) and formula upon the structure and bond type to be expected in any given case.

The order of the elements along the horizontal is essentially the same as that for the alloys; aluminum has been shifted and ammonium ion added, to facilitate classification. The sizes of the ions within a periodic group increase from left to right for the metallic elements, and from top to bottom and right to left for the non-metallic; so that in any specific area (*e. g.*, the alkaline earth oxides, sulfides, selenides, and tellurides) the inter-ionic distances increase in the directions away from the upper left-hand corner of the area.

The electronic structures, which determine the polarization properties of the ions, are indicated across the top of the chart.

The crystal structures of the individual compounds are indicated by symbols. For the sake of simplicity, only certain groups of structures have been given. The purpose of the chart is not to record specific crystal structures, but to systematize certain types of structures. It must also be emphasized that the chart does not necessarily include all the known crystal structure data for binary compounds.*

The design of the symbol (see legend) tells something of the type of bond in the crystal in question. The horizontal symbols indicate lattices which are believed to be essentially ionic. The vertical ones refer to lattices believed to be atomic, in which the forces are essentially covalent. In the layer lattices both ionic and covalent forces are found, as well as weak van der Waals forces. The diagonal symbols refer to crystals which have metallic properties, suggesting the presence, at least in part, of the metallic bond.

The broken-line symbols are those for compounds in which it is generally conceded that the ionic bond predominates, regardless of the crystal structure. All other types are in solid line symbols. Of course, it is impossible to say where, in the transition from ionic bond to covalent bond, the ionic bond ceases to predominate, so that this division must be somewhat arbitrary.

The stoichiometric formulas of the compounds are indicated indirectly by the symbols for their crystal structures. A line with no numeral signifies a compound with the general formula AX; the AX_2 compounds are designated by the number 2, the A_2X_3 compounds by 2–3 and the AX_3 compounds by 3.

There are two generalizations, clearly demonstrated by the chart, which are of particular interest.

1. The Structures of the Elements.—Following the elements along the diagonal from the origin toward the upper right, there is a continuous transition from the metallic, to the atomic, to the molecular type of structure. The structure of each element is consistent with the area in which it occurs, areas which have been defined on the basis of the structural characteristics of their *binary compounds*. The elements up to and including gold have the close-packed structures of true metals; those from zinc to tin have abnormal metallic structures. At tin a change occurs; white tin is metallic, while gray tin, germanium, silicon, and diamond form atomic crystals in which the atoms are held together by covalent bonds throughout the crystal. Graphite is a layer lattice, and bismuth, antimony, arsenic, and one form of phosphorus form layer lattices; the bonds within the layers are covalent and the nature of the bonds between layers must account for the metallic properties of these elements. Tellurium and selenium form chain structures; the bonds within a chain being covalent while those between chains must be in some measure metallic. Thus the diamond is one huge molecule, with covalent forces throughout—a true atomic crystal. Arsenic is built of layer molecules, covalent forces extending in only two crystallographic directions. Selenium is built of chain molecules, covalent forces prevailing in only one direction. Finally, in sulfur, iodine, and other strongly electronegative elements the molecules are disconnected and exist in the crystals as discrete building units. Thus the transition, atomic type to molecular type structure, is completed.

2. Influence of Electron Density upon the Type of Compound Formed.—The chart indicates an interesting

* The data have been taken, for the most part, from:

EWALD, P. P. AND HERMANN, C., "Strukturbericht 1913–1928," Leipzig, **1931.**

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BERNAL, J. D., *Trans. Faraday Soc.*, **25**, 367–79 (1929).

WESTGREN, A. AND CO-WORKERS: Numerous papers.

International Critical Tables, Vol. II, Alloys. McGraw-Hill Book Co., New York City.

A relatively small number have been taken from recent periodical literature.

empirical relationship between the electron concentration (the number of valence electrons per atom) of a binary system and the general type of compound formed. The trend is summarized in Table 1.

Finally, it may be observed that the transition from metallic, to atomic to molecular crystals of the elements, as described in the preceding section, is entirely consistent with the relation between electron density and bond type brought out in Table 1. Thus, the electron density of diamond is 4, that of arsenic is 5, of selenium, 6; and of iodine, the last stage in the transition from the atomic to the molecular crystal, 7.

The effect of ionic or atomic sizes, of the relative valences and the electronic structures of atoms or ions, upon the crystal structures and properties of the compounds which they form, will be developed in detail later.

TABLE 1

INFLUENCE OF ELECTRON DENSITY UPON THE TYPE OF BINARY COMPOUND

Valence Electrons per Atom	*Electron Concn.*	*Bond Type*	*Description of Binary System*
< 3:2	<1.5	Metallic	Alloys.
3:2	1.5	Metallic	*Beta phases.* Secondary solid solutions. Metallic properties.
21:13	1.6		*Gamma phases.* Intermetallic compounds. Evidence of covalent bond.
7:4	1.75		*Epsilon phases.* Intermetallic compounds. Evidence of covalent bond.
{5:2 {6:2	{2.5 {3.0		*NiAs and FeS_2 structures.* Some metallic properties, but more like covalent compounds.
8:2	4.0	Ionic or covalent	AX compounds. Ionic or covalent.
24:5	4.8		A_2X_3 compounds. Ionic or covalent.
16:3	5.3		AX_2 compounds. Ionic or covalent. In layer lattices, molecular bonds between layers.
24:4	6.0		AX_3 compounds. Usually layer lattices. Molecular bonds between layers.
32:5	6.4	Molecular	AX_4 compounds. Compounds of two electronegative elements.
14:2	7.0	Molecular	I_2. A typical molecular crystal.

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(1) STILLWELL, C. W., J. CHEM. EDUC., (*a*) **10,** 590–9 (1933); (*b*) **10,** 667–74 (1933); (*c*), **11,** 159–68 (1934).
(2) GRIMM, H. G., *Angew. Chem.*, **47,** 53–8 (1934).
(3) HUME-ROTHERY, W., MABBOTT, G. W., AND EVANS, K. M. C., *Phil. Trans. Roy. Soc.* (London), **A233,** 1–97 (1934).

RÉSUMÉ *of* CHEMICAL ENGINEERING EDUCATION *in* UNITED STATES*

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A MOST searching investigation of chemical engineering education in the United States is being carried on by the American Institute of Chemical Engineers' Committee on Chemical Engineering and the S. P. E. E. Committee on Chemical Engineering. Reports on the activities of the first committee are available since 1910 and can be found in the *Transactions of the American Institute of Chemical Engineers* and in bulletins issued annually by the Institute. An attempt is made to collect together the references relative to the activities of the Committee on Chemical Engineering Education and to supplement the data with those of the school year 1933–34.

The first conference on chemical engineering education was called in 1925 (*15*), at which a number of papers were read and considerable discussion took place. Badger (*1*) read a paper on the nomenclature and division of time in chemical engineering courses; James (*10*) on entrance requirements; Lewis (*12*) on qualifications of the faculty; Jackson (*9*) on the length of the curricula; Withrow (*20*) on four-, five-, and six-year chemical engineering courses; Hixson (*8*) on laboratory work; and Curtis (*6*) on local administration of chemical engineering. All teachers of chemical engineering subjects will find this compilation of papers and the attending discussion quite interesting reading.

Resulting from this conference were the numerous questions submitted and answered in the 1927 report of the committee (*3*). The questions dealt mainly with course matter, such as emphasis, specialization, functional *vs.* technical courses, economics, shop courses, foreign languages, etc.

In 1928, White (*18*) presented a paper at Niagara Falls at the meeting of the American Institute of Chemical Engineers, discussing much of the early history of chemical engineering education in the United States, the relation of chemical engineering education to other engineering professions and curricula, the activities of the education committee, a distribution of the time devoted to various classes of courses in the chemical engineering curricula in 1925, and a suggested distribution as proposed by the committee (*4*).

A questionnaire was sent out by the author of this paper to obtain more recent data from the 93 colleges and universities teaching chemical engineering, or granting chemical engineering degrees. As is usual in such cases, the returns were incomplete and the writer had to seek information elsewhere. The college and

* Paper read before the S. P. E. E. conference on chemical engineering, Ithaca, N. Y., June 19–21, 1934.
† Chairman S. P. E. E. Committee on Chemical Engineering.

university catalogs are the official sources of information from which most of the data were obtained. Differences in presentation of subject matter and curricular data required a translation which may still need some revision. The data in the catalogs are not always complete. The combined questionnaire and catalog data have been compiled in the accompanying table.

TABLE

DATA ON CHEMICAL ENGINEERING EDUCATION

INSTITUTION	SUPERVISION	ENROLMENT DATA: Undergrad. 1923	Undergrad. 1928	Undergrad. 1931	Undergrad. 1933	Staff 1923	Staff 1928	Staff 1933	GRADUATE COURSES	ENG. EXPT. STA.	CHEM. ENG. OPERATIONS EQUIP'T	SEMESTER CREDIT HOURS: Chem. Eng. Oper. Lecture	Chem. Eng. Oper. Lab.	Chem. Eng. Design	Chem. Eng. Projects (or) Problems	Chem. Eng. Stoichiometry	Chem. Eng. Economics & Seminar	Ind. Chem. Lecture	Ind. Chem. Lab.
Alabama Poly. Inst.	ChPh	...	...	143	...	..	..	7½	+	+	P	..	..	1	2	..	..	6	2
Alabama, Univ. of	Ch	...	...	88	...	..	..	7	+	+	P	..	..	2	..	3	..	6	..
Arkansas, Univ. of	Ch	...	...	52	...	..	..	4½	+	+	P	..	..	..	..	..	..	6	..
*Armour Inst. of Tech.	I	...	...	113	...	..	..	9½	..	..	G	5	6	..	..	..	..	5	5
Bucknell University	I	40	45	...	55	1	5	6	+	+	G	6	4	3	3	3	3	6	..
*Calif. Inst. of Tech.	Ch	...	...	29	...	..	..	2	+	..	P	8	..	..	..	..	..	4	..
*Carnegie Inst. of Tech.	I	24	35	...	63	7	10	14	..	+	VG	3	..	..	..	..	..	2	..
*Case School of App. Science	I	32	76	...	93	7	8	16	+	..	G	3	2	2	6	2	3	6	6
Catholic U. of Am. (B)	Ch	...	...	17	...	..	..	3	+	..	P	3	..	..	..	1	1	3	..
*Cin., Univ. of	I	...	...	255	...	..	..	6	+	..	G	6	5	2	2	..	2	4	Coöp.
Colorado, Univ. of	ME	...	...	80	...	..	..	4	+	+	P	4	..	4	..	1	4	4	..
*Columbia Univ.	I	...	...	144	...	..	..	10	+	+	VG	5	4	2	3	2	5	5	3 5th yr.
Cornell Univ.	ChtEng	...	...	...	...	..	..	..	+	..	G	..	4	3	..	..	3	6	
Drexel Institute	I	14	64	...	139	11	12	10	..	+	VG	6	3	3	..	..	..	4	2 Coöp.
Detroit	ChI	...	...	...	...	..	..	..	..	..	P	..	..	..	..	..	..	..	..
Dayton University	Ch	...	...	54	...	..	..	2	..	..	P	4	..	..	..	..	2	6	..
Florida, U. of	Ch	6	8	...	38	1	1	1	+	+	F	3	3	..	..	..	..	6	2
Georgia Tech.	ChI	25	55	...	120	2	2	3	+	+	F	5	2	..	..	2	..	5	Coöp.
Idaho, Univ. of	Ch	...	...	27	...	..	..	2	+	+	P	6	..	..	3	..	..	2	..
*Illinois, U. of	Ch	163	105	...	176	7	12	9	+	+	G	8	2	..	5	..	2	4	2
*Iowa, Univ. of	Ch	...	...	74	...	..	..	4	+	+	G	6	..	..	..	..	..	8	..
*Iowa State College	I	94	179	...	225	3	6	6	+	+	VG	6	4	4	3	2	4	6	2
Kansas State Coll.	Ch	...	...	77	...	..	..	4	+	+	F	5	..	..	..	3	..	6	4
Kansas, University of (B)	Ch	...	...	76	...	..	..	5	+	+	P	..	..	..	..	..	..	6	..
Lafayette College	Ch	...	...	24	...	..	..	2	+	..	F	3	..	..	4	..	1	3	..
*Lehigh University	Ch	...	...	206	...	..	..	8	+	..	G	3	4	..	1	..	..	2	3
*Louisville, U. of	I	...	...	37	45	..	..	3	+	..	G	4	..	2	4	4	..	8	..
Maine, Univ. of	Ch	...	...	98	...	..	..	3	+	+	P	..	..	..	..	..	2	9	..
*Mass. Inst. of Tech.	I	288	233	...	259	18	25	18	+	+	VG	10	Sp.	3	Sp.	..	1	8	Sp. 5th yr.
Mich. State College (B)	I	...	...	81	...	..	..	4	+	+	F	..	3	..	..	..	..	4	6
*Mich., Univ. of	I	274	165	...	252	12	12	10	+	+	VG	6	2	..	5	..	..	6	2
*Minn., Univ. of	I	106	217	...	222	3	5	14	+	+	G	4	4	2	4	..	2	6	4
Missouri, U. of	I	40	65	...	50	..	1	1	+	+	F	5	5	..	..	..	..	3	..
Montana State College	I	...	...	...	...	..	..	..	+	+	F	8	3	..	..	..	2	6	..
Newark College of Engineering	I	32	48	...	167	3	5	8	..	..	F	4	4	..	..	..	..	4	4
*New York University	Ch	...	...	...	56	..	..	1	+	..	F	6	2	2	4	..	..	5	..
Notre Dame	I	...	...	...	...	..	..	..	+	..	F	8	..	..	..	2	..	6	8
North Car. A. & M.	I	...	...	136	...	..	..	2	+	+	P	6	..	..	..	2	3	6	..
North Car., Univ. of	Ch	...	8	...	45	..	1½	2	+	..	P	6	1	..	6	3	..	6	1
Nebraska, Univ. of	Ch	...	...	78	...	..	..	4	+	+	P	..	..	..	..	..	..	5	..
North Dakota, U. of	I	...	...	26	...	..	..	2	+	+	P	..	..	..	..	..	..	6	..
*Ohio State U. (B)	I	...	139	220	172	7	7	7	+	+	VG	2	6	4	4	3	2	2	5
Oklahoma A. & M.	Ch	...	...	54	...	..	..	2	+	+	F	6	1	..	..	..	..	6	1
Oregon State Coll.	Eng	78	113	...	65	1	2	2	+	+	G	6	2	1	4	1	3	2	1
Penn. State College	Ch	...	...	125	...	..	..	3	+	+	P	8	2	..	4	2	2	2	2
Penn., U. of	Ch	...	...	74	...	..	..	2	+	..	P	3	2	..	..	..	..	6	2
*Purdue, Univ. of	I	183	229	...	421	2	4	8	+	+	VG	4	..	2	2	3	..	6	..
*Pittsburgh, Univ. of	I	...	...	81	...	..	..	2	+	..	F	3	6	..	2	3	..	6	6
*Princeton University	I	10	20	...	89	4	4	5	+	..	G	3	2	..	2	..	8	6	2
*Poly. Inst. of Brooklyn	I	...	...	109	...	..	..	5	+	..	G	6	2	..	8	..	..	2	2
Pratt Institute	ICh	130	80	...	90	7	6	5	..	..	G	3	3	3	..	1	1	4	8
*Rensselaer Poly. Inst. (B)	I	...	...	215	...	..	..	8	+	..	P	4	..	4	4	4	4	4	..
Rice Institute	Ch	...	...	126	...	..	..	6	..	..	P	6	4	..	3	..	..	4	4
Rochester, U. of	M.Eng	...	...	35	...	..	..	2	..	..	P	..	..	..	..	..	..	6	..
Rose Polytechnic	I	35	17	...	38	3	2	3	+	..	G	3	2	..	5	5	..	4	2
Syracuse, U. of	I	...	...	30	...	..	..	1	+	+	F	5	..	..	..	..	..	6	..
Tennessee, U. of	Ch	...	...	78	...	..	..	4	..	+	P	..	..	..	..	..	..	6	..
Texas A. & M.	ICh	...	...	189	...	..	..	8	..	+	P	..	..	..	..	..	..	9	1
Tulane University (B)	I	...	...	53	...	..	..	6	+	+	G	6	8	6	..	..	..	6	..
Virginia, U. of	I	...	...	39	...	..	..	2	+	..	F	6	..	..	5	..	..	6	..
Virginia Polytech.	ChI	41	51	...	165	1	2	2	+	+	F	6	6	..	..	..	2	4	..
Washington U. (St. Louis, Mo.)	I	10	15	...	21	1	2	2	+	..	F	6	6	..	..	..	..	..	..
*Washington, U. of	Ch	...	...	130	...	..	..	5	+	+	F	6	3	..	4	..	6	10	..
Washington State College	Ch	...	...	39	...	..	..	3	+	+	P	..	..	..	..	..	..	4	..
West Va. Univ.	I	38	54	...	88	1	4	4	+	+	F	3	2	..	..	..	..	5	2
*Wisconsin, U. of	I	51	93	...	186	1	5	9	+	+	F	6	4	..	4	..	..	5	4
Worcester Polytech.	Ch	...	...	96	...	..	..	5	+	..	P	6	..	..	4	2	..	2	3
Wyoming, Univ. of	Ch	...	...	4	...	..	..	1	+	+	P	..	..	..	..	..	..	..	..
*Yale University	I	...	35	...	42	..	..	3½	+	+	VG	6	3	3	6	2	2	6	..

* Accredited Institutions, Amer. Inst. Chem. Engr.

INSTITUTIONS AND DEGREES

The Committee on Chemical Engineering Education (*5*) has accredited twenty-four institutions as having faculty, equipment, and curricula which in its opinion are adequate for training chemical engineering students. Sixty-nine institutions still await accrediting. How many of these institutions should drop the claim that they are teaching chemical engineering is a question not easily answered, because many of these non-accredited institutions need but little change before they, too, are fully qualified. In 1920 Little (*14*) reported that 128 institutions gave instruction in chemical engineering, but that only seventy-eight replied to his questionnaire.

The degree of Bachelor of Science in Chemical Engineering is the standard degree granted after the completion of four years of study; the following six grant the degree of Bachelor of Chemical Engineering: Catholic University of America, University of Kansas, Michigan State College, Ohio State University, Rensselaer Polytechnic Institute, Tulane University. Cornell University grants the professional degree of Chemical Engineer for a fifth year of study, following the Bachelor of Chemistry degree. Columbia University grants the professional degree for six years of course work, M. I. T. for a fifth year in the School of Engineering Practice, and Virginia Polytechnic Institute and the University of Kansas for a fifth year in the course.

When Curtis (*6*) presented his paper on the local administration of chemical engineering in 1925, there were few independent departments of chemical engineering. Today there are thirty-three institutions with independent departments and a possible four more may be added before next year; there are seven with joint departments bordering on independence, and all the remainder, but two, administered by the department of chemistry. Two institutions administer the chemical engineering work under the mechanical engineering departments. The supervision of the curricula is not a measure of the quality of work given, but as important a branch of engineering as chemical engineering should shoulder the responsibility for its own curricula.

ENROLMENT

The enrolment data showed almost as great a range as other statistics on chemical engineering education. Inadequate returns forced the writer to turn to other sources of information, among which the most important was that compiled by W. C. John (*11*). The statistics obtained showed a marked increase during the last decade; a ratio increase from 4 to 5 to 7 is apparent from the enrolment data of 1923 to 1928 to 1933. Accordingly, the enrolment of 1933 is 6600 (*19*), while that of 1934 should be twenty per cent. more, possibly near 8000.

INSTRUCTORS

The data on instructors in chemical engineering are difficult to obtain, since all the questionnaires were not returned. Using the compilation on American Colleges and Universities gave only small aid, because in many instances the chemical engineering instructors were listed with the engineering group, while in other cases they were grouped with the chemistry instructors. Basing the increase in instructors on the basis of the returns received from the questionnaires the ratio increase of 4 to 5.6 to 7 paralleled the enrolment increase. A closer study of the data showed that this ratio did not apply to the larger institutions, where there existed many cases of retrenchment, while in the smaller institutions the ratio increase was considerably larger.

FACILITIES

There exists considerable ground for dispute as to the adequacy of the equipment available for student use in chemical engineering laboratories. Just what constitutes chemical engineering equipment and what constitutes chemical equipment is impracticable to differentiate. However, an arbitrary rating of poor, fair, good, very good was established; the description of the equipment as written up in the institutional catalogs and in the questionnaire was used in the rating. In general, where no specific laboratory course in chemical engineering operations or processes is to be found, a rating of poor is given. Nine institutions are given a very good rating, indicating that they have considerably more types of equipment and of greater capacities than that barely essential for student instruction. Sixteen institutions are classed as good, or adequately equipped. Twenty institutions have a fair rating, with equipment little better than the stock industrial chemistry laboratory set-up. The remainder of the institutions should acquire more laboratory equipment and facilities for adequate instruction purposes.

Iowa State College, University of Louisville, and Purdue University have separate buildings for housing chemical engineering; The University of Dayton, University of Arkansas, University of Notre Dame, and Rensselaer Polytechnic Institute are contemplating the erection of new buildings to house their departments of chemical engineering. Carnegie Institute of Technology has recently opened its new chemical engineering laboratory. Bucknell University, Georgia School of Technology, and Vanderbilt University are adding new equipment, while the University of Maryland and the University of Tennessee are strengthening their courses and adding new equipment.

Engineering experiment station provides laboratory facilities for large scale experimentation at forty-two of the above institutions. It is difficult to obtain information on the industrial fellowships which are assigned to chemical engineering departments, but unquestionably the number is quite high. The most recent compilation on scholarships and fellowships supported by industry was reported by West and Hull (*17*).

COURSES

The discrepancy among the institutions in the teaching of chemical engineering students and granting them baccalaureate degrees in Chemical Engineering for the training received is rather marked. There is some marked improvement in the condition today over that reported by Little (*14*) in 1920. Either because of some misunderstanding of the nature of chemical engineering, or possibly because of some error in the official bulletins of the institutions, the data show that eleven institutions give no course work, lecture or otherwise, in chemical engineering unit operations, while twenty-nine do not provide for the application of the principles of unit operations by giving laboratory work. Industrial chemistry lectures are given at all the listed institutions; thirty-two of these provide laboratory instruction in industrial chemistry.

Design is taught at twenty-one institutions, both equipment design and chemical engineering plant design. Special problems and projects, or minor research problems, are provided for in the curricula of thirty-two institutions. Stoichiometry is taught at twenty-three institutions and chemical engineering economics at twenty-three.

Of the eight course subdivisions indicated, five institutions give instruction in all eight, sixteen in six or more subdivisions, and twenty-seven in five or more subdivisions. This last number would seem to be the minimum number of subdivisions of instruction adequate for chemical engineering academic instruction. There are six institutions giving but one course, fourteen giving not over two, twenty not over three courses, while thirty-six give instruction in not more than four course subdivisions in chemical engineering.

GRADUATE STUDIES

Graduate degrees are granted in all but nine of the tabulated institutions. The facilities available at most of the institutions indicate that very little is lacking for at least some kind of chemical engineering investigative work. However, the Committee on Graduate Instruction, of the American Council on Education, reported that only ten were adequately equipped with staff and facilities for granting graduate instruction leading to the doctorate.

There have been, and will continue to be, seminars and conferences on chemical engineering teaching for quite some time. Badger (*2*), Curtis (*7*), and Lewis (*13*) gave excellent papers at the Chemical Engineering Summer Session at Ann Arbor under the auspices of the S. P. E. E. The conference held at Ithaca on chemical engineering education was an immediate follow-up of the Michigan session. Another conference on chemical engineering education was held May 13–15, 1935, at Wilmington, under the auspices of the American Institute of Chemical Engineers, while the S. P. E. E. Committee on Chemical Engineering sponsored a conference on laboratory instruction in chemical engineering at Atlanta, June 24–25, 1935. The good that resulted from these conferences will make itself felt in better laboratory facilities, more adequate instruction, and better curricula for chemical engineering students, with a probable increase in accredited institutions by the American Institute of Chemical Engineers' Committee on Chemical Engineering Education. The second phase of the program laid down by the Engineering Council for Professional Development (*16*) seems to be well taken care of by existing active agencies.

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SPECIAL PROBLEMS *in the* TEACHING *of* CHEMISTRY*

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THE teacher of chemistry today is not only intensely interested in his subject and its development, but is likewise greatly concerned with the problems that arise in the presentation and teaching of the subject to students. He is fully conscious of the fact that his methods are by no means perfect in application nor in the results he obtains, but, in general, he strives to achieve certain rather definite ends by making changes in his presentation—changes which are based upon his past experiences, and in part upon the experiences of others.

It is to be admitted frankly that no definite rules can be formulated for the teaching procedures, since what may apply to one individual may not apply to another. Every teacher has his own characteristic points of attack, based upon previous experience, and a method of approach which for him is very successful might very well prove to be equally unsuccessful in the case of another individual. If experience of the individual is all that is necessary for the promotion of good teaching, why do we spend so much effort and time on teaching methods and schemes? It is undoubtedly quite useless to tell one how to teach and what to teach. The value of our educational studies is that they relate and describe the experiences of others in similar attempts. These results may have little influence upon the individual as a teacher of the subject in question but, on the other hand, they may give him something to think about, some different viewpoints, and above all they do give him the benefit of the experiences of others in similar fields of endeavor. It is from this point of view that the problems described in this paper are presented.

One problem which has received a great deal of attention is the order of presentation of the subject matter of general chemistry. Again, no definite rules or methods will be found to apply to all teachers. However, it may be added that the order of presentation is quite stereotyped and uniform, and very few changes have taken place during the past two or three decades. I had an experience a few years ago which led me to initiate certain changes in the teaching of general chemistry.

One day, following a lecture given in the early part of the course, a student from the class came to me with this remark. He said that he had observed on several occasions that when I wanted some information during a lecture, concerning some element and its properties, instead of examining my notes I merely turned around and looked at the chart of the periodic table posted on the wall above; and to his surprise, I usually obtained the information I was seeking. Then the student commented, "If the chart of the elements is as valuable as this to you, why would it not be of value to us even in the beginning of the subject?" To me this was a very interesting comment; I had never previously thought of the problem in this light. It illustrates a point which one so often observes in teaching—that the student represents one of the best controls available for judging the effectiveness of teaching procedures.

On the basis of this comment, the following year I began the course in elementary chemistry, for students without high-school preparation in the subject, in an entirely different manner and have continued this procedure for several years, since for me the scheme works out very satisfactorily. After the introduction of the subject in which the application of chemistry to everyday life, the different fields of chemistry, and the meaning of chemistry as a science are discussed, the concepts of matter and energy are introduced. Then follow consideration of the different states of matter, species of matter (the elements), early attempts at classifications of the elements (from Prout to Mendeléeff), and finally, the Mendeléeff periodic table. The latter, of course, cannot be discussed in detail at this point but no difficulty is found in conveying the principal ideas of the table to the student.

When the different species of matter are discussed, the question naturally arises whether or not the elements are composed of simpler species of matter, and, if so, what may be building blocks or units of matter. This leads to an introduction of Dalton's atomic theory, then to the discovery of the electron, X-rays, and radioactivity. Atomic structure is the next logical topic on the program. Here is stressed the electronic configurations of the elements in relation to their positions in the periodic table, in relation to isotopes and atomic numbers, etc. Atomic nuclear constitution is considered briefly. A few simple, well-known reactions between familiar elements are then introduced in order to illustrate the part played by the electron in such processes. The subject of combustion and the reactions involved serve well to illustrate the point.

To complete this program a period of about four weeks, in which there are three one-hour lectures and one hour for conference each week, is required. To

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me this procedure has been found very satisfactory for several reasons. I have found that with this introduction the students become greatly interested in the subject, for they become acquainted immediately with one of its most fascinating phases. In addition, the subjects of valence, of oxidation and reduction, and of ionization are much less difficult for the student to grasp, since he has some theoretical background from which he has derived mental pictures applicable to an interpretation of these concepts.

A criticism of this procedure is apparent; the theories precede the facts whereas, in reality, the theories developed from the facts. However, is there any good reason for adhering to a chronological order of presentation except for the purpose of showing the earlier development of the science? It appears that the chief aim of the elementary chemistry course is to teach the principles of chemistry. Why not, then, use all the tools available to accomplish this end? Most of the students engaged in a study of general chemistry are in the process of preparing for a profession which demands a knowledge of the principles and technics of chemistry. In consideration of this fact, any method which serves to attain these objectives is not only legitimate but desirable. Again the question of the individual teacher arises; others may have different methods for accomplishing the same purpose; the method described here is merely one of many in approaching the problem.

The introduction of newer concepts into an elementary chemistry course constitutes another problem for the teacher; what concepts should be included and what concepts should be excluded? Naturally, it is impossible and impractical to include some of the more recent ideas since a clear understanding of them is dependent upon a training in the physical sciences far in advance of that of the average student of elementary chemistry. On the other hand, these newer concepts are often quite simple in character, and directly applicable to the principles of the subject. It has appeared to me that it is absolutely useless to include any new concept which does not have a direct bearing upon, and which cannot be used in, the course. If the concept can be used to explain and interpret the principles of the subject, or if some of the descriptive material of the course may be related to the concept, it is highly desirable. On the other hand, if the concept is introduced as a fact just because it is new and then left "high and dry," it has no place in the course. Such an introduction of the subject leads to confusion in the mind of the student. He has enough isolated facts with which to contend as it is. If the teacher cannot find any application of a concept to the course, certainly the student will not discover it.

By way of example one might mention the different forms of hydrogen which have been discovered in the past few years. Heavy hydrogen (deuterium) finds considerable application to the subject matter covered by the student of elementary chemistry. The fact that it is an isotope of hydrogen which may be completely separated from the lighter isotope, identified as such, and studied in pure form, is of considerable interest to the student in that it has a direct bearing upon the constitution of matter. Its discovery has given the beginning student a far better general idea of isotopes. Its wide application is readily apparent.

In contrast one might cite the ortho and para forms of hydrogen which were predicted a few years ago and later identified. This discovery is of great importance to the advancement of chemistry, but the significance of the parallel and antiparallel spins of the nuclei of the hydrogen molecules is not readily understood by the student; nor do these two types of hydrogen molecules play any part in the development of concepts presented to the student of elementary chemistry. It is advisable to omit the latter, and equally important to include the former.

The concept of the activity, and activity coefficient, of ions falls in the same category. Some of the texts of elementary chemistry introduce these terms with brief, loosely conceived, and inadequate statements. Even the more advanced students of the subject would find great difficulty in obtaining a clear interpretation of the statements. Moreover, it is rarely that these terms are used or applied further in the text in which they are introduced. It is natural that such a treatment of the concept should lead to confusion of the student.

About fifteen years ago an interionic attraction theory was developed by Debye and Hückel to explain the behavior of strong electrolytes in aqueous solutions. The older theory of Arrhenius assumed incomplete ionization even for strong electrolytes on the basis of the colligative properties of their solutions; however, it was recognized that for such solutions the law of mass action is not obeyed, whereas in the case of solutions of weak acids and of weak bases it is obeyed very well, especially at lower concentrations. The newer theory of Debye and Hückel assumes complete ionization of strong electrolytes in dilute solutions, and accounts for the deviations in their colligative properties from those predicted on the basis of the behavior of non-electrolytes, by a decrease in the number of effective particles in solution, due to the attractive forces operating among the ions, with resultant formation of ionic clusters. On this basis strong electrolytes are at least very nearly completely ionized in dilute solutions, and for our purposes in the teaching of the undergraduate courses we may assume complete ionization.

There has been a tendency to present in textbooks of elementary chemistry brief statements concerning the interionic attraction theory without any attempt to apply the results of the theory. Thus strong electrolytes of the binary type such as NaCl, KCl, HCl, HNO_3, etc., are listed as about 90% ionized in 0.1 molar solutions. Such a situation must necessarily confuse the student who encounters the subject of ionization for the first time. It is much simpler for both teacher and student to assume, as an approximation, that all strong electrolytes are completely ionized; and it is undoubtedly more correct to make this assump-

tion. Use of this concept leads to a simpler treatment of ionic equilibria, and to elimination of the rather ambiguous term, "degree of ionization of strong electrolytes."

Another problem arising at this point relates to a more exact interpretation of the condition of ions in solution than is usually presented. A definite effort is being made to introduce some of the more modern concepts of acids and bases to the beginning student. These concepts are based upon well-founded facts and are not difficult to comprehend. One such concept is that an acid is any substance capable of yielding protons, while a base is a substance that accepts, or combines with, protons. But I feel strongly that if this concept were to be carried through in its entirety in the presentation of elementary chemistry, it would be so general in character that the student, to whom a rather limited knowledge is available, would be more confused than benefited. A certain knowledge of the subject is required before the individual is able to appreciate the meaning of the concept in its various diversifications.

However, a more serious problem is associated with these concepts of acids and bases. This involves the introduction of the hydronium or oxonium ion, H_3O^+. The arguments for the existence of such an ion are clear and justified, and are supported by well-established facts. The only question which arises is that of the exact composition of the ion; whether one or more molecules of water are present in the complex. Frankly, we do not know how many molecules of water are involved in the formation of the complex ion. It is written as H_3O^+, since the formula is simple, and since experimental evidence indicates that the hydrogen ion in an aqueous medium is probably the least hydrated of all ions. But the important point arises here; why should the hydrogen ion be made the exception in this respect? We have good evidence for the hydration of all ions in aqueous media, hydration which is in many cases much greater than that of the hydrogen ion. If we write the hydrogen ion as H_3O^+, then all other ions should be written in a similar form, associated with water molecules, in order not to convey an erroneous impression The impracticability of this procedure is obvious. Two additional points arise in this connection. First, all the hydrogen atoms of the complex ion, H_3O^+, are undoubtedly equivalent. How is this to be explained satisfactorily without leaving any doubt in the mind of the beginning student? Secondly, there may appear to the student some question regarding the applicability of the law of definite proportions. Our efforts in teaching should be in the direction of simplification of the presentation of concepts, with the sacrifice of exact details, rather than toward complexity and confusion.

The segregation of students according to previous training, ability, and future application of the subject represents a problem which has received considerable comment. However, for numerous reasons it appears that many of the difficulties associated with this problem are gradually disappearing. Chief among them is the fact, as observed at the University of Chicago, that more and more students enter the University each year equipped with training in high-school chemistry. The number of pupils entering the University of Chicago course designed for students without high-school training in the subject is diminishing rapidly, so we are now at the point of discontinuing such a course. This condition has also been affected by the initiation of the general course in the physical sciences. Some students without high-school chemistry training first spend a year in the physical science general course before entering the regular chemistry courses. This training is more than the equivalent of the high-school chemistry prerequisite; accordingly, students having it are permitted to enrol in the elementary chemistry course designed for those entering with high-school preparation. Moreover, students who formerly would have enrolled in the elementary chemistry course for its cultural value, now omit the rigid chemistry training and instead enrol in the much broader physical science general course, which serves their needs infinitely better.

Evidently some of the problems of segregation are disappearing; the elementary chemistry course today enrols chiefly students directing their efforts toward some profession that demands an understanding of the principles and technics of chemistry. Within this group there is an opportunity for segregation on the basis of ability of training which is desirable and profitable. The segregation that we have made relates only to our weekly conference sections and to the laboratory. The class is divided into small groups, usually not exceeding twenty in number, which meet once a week for informal discussion and exchange of ideas concerning the lecture and laboratory work. Students having a poor or no preparation in physics are segregated into one, or two, of these groups, as the case may be. Others, having shown outstanding ability, are placed in another group. The advantages of such segregation are evident. Students of unusual ability as well as those having had an intensive laboratory training in high school are given additional experiments to perform. (Repetition of experiments previously carried out in high school is not required.) Some of these experiments are in the nature of problems accompanied by a minimum of instruction; they tax the ability and ingenuity of the ablest student.[1]

We have not made any attempt to segregate students on the basis of their intended professions; nor does such a procedure seem advisable. It is true that the students of the elementary chemistry courses—general chemistry, qualitative analysis, and organic chemistry—are diversified in their wants and objectives. Many of them are planning to enter the fields of medicine, dentistry, agriculture, or engineering, while some have chosen chemistry as a profession. Nevertheless, the fundamental principles of chemistry are essential to all these professions. Any specialization in concession to sup-

[1] For a description of the character of these experiments see SCHLESINGER, J. CHEM. EDUC., **12**, 524 (1935).

posed professional needs necessarily leads to a dilution of the fundamentals of the subject, with unsatisfactory results. It is perhaps true that the preliminary training in chemistry as we now give it includes more descriptive material, more laboratory work, and greater repetition and stress of the principles than is necessary to satisfy the requirements of some professions. If this is true, then a study should be made to determine the desirability and feasibility of making changes in the teaching of elementary courses of chemistry without sacrificing the fundamental aspects of the subject. Activity in this direction is now in progress in one of our large universities in which the elementary chemistry courses contain a high percentage of pre-medical students. It will be interesting to follow the results of this and similar educational experiments.

The statement has often been made by the teacher of elementary chemistry that "if the student is not able to solve a simple mathematical problem relating to the subject, he does not understand the principle involved in the problem." I am not at all sure that such a statement is correct; however, I am certain that the converse statement is incorrect; that is, "if the student is able to solve the mathematical problem relating to the subject, he does understand the underlying principle." Ability to solve the problem may or may not imply understanding of the significance of the principle. Too often it does not; the mathematical operations are carried out mechanically with little or no appreciation and realization of the meaning of the operations and their results.

Let us illustrate this point by the selection of a rather striking example. The student is given the percentage composition of a substance containing two elements, which we shall designate by the symbols A and B, and is asked to derive its formula. Let us suppose that the compound is composed of 60% A and 40% B by weight. The atomic weight of A is given as 40 and that of B, 20. Automatically, through a knowledge of former examples, the student divides 60 by 40 and obtains 1.5; then divides 40 by 20 and obtains 2. He now knows the formula might be written $A_{1.5}B_2$; but he does not stop here, he multiplies the values of both A and B by 2 and finally obtains the empirical formula A_3B_4, which is correct. Why does he multiply by 2 in this last operation? If he can answer that question satisfactorily, he understands the underlying principle; if he cannot, he does not know what is really involved in his calculation. He might even fail to realize why he divided 60 by 40, and 40 by 20. Could not other values besides 60 and 40 be used, and if so what ratio must they bear to each other? This is only one of many types of calculations the student can readily learn to manipulate without the slightest idea of the principles involved. It is a problem for the teacher to invent methods by way of illustration, or other means, to enable the student to grasp the significance of the calculations under consideration; otherwise they are apt to be meaningless and useless, aside from a development of arithmetical proficiency.

The well-known proportion formula likewise falls into this classification. As an example let us consider the equation for the reaction which proceeds when metallic zinc is treated with hydrochloric acid solution:

$$\underset{65.4\text{ g.}}{Zn} + \underset{73\text{ g.}}{2HCl} = \underset{136.4\text{ g.}}{ZnCl_2} + \underset{2\text{ g.}}{H_2}$$

The equation states that when 65.4 grams of zinc is treated with an excess of hydrochloric acid, 2 grams of hydrogen gas is evolved. The student may be asked to calculate the weight of hydrogen gas liberated when 20 grams of zinc is used. A proportion of the following type may be set up:

$$\frac{65.4}{20} = \frac{2}{x}$$

where

$$x = \frac{2 \times 20}{65.4}$$

A student may readily learn to construct such a proportion for a number of similar problems although he may not understand why such a formulation is made. But he might very well construct an incorrect proportion, since there are several incorrect as well as correct arrangements of the four quantities involved in the proportion. Certainly such a condition is far from satisfactory.

The situation may be easily remedied by thorough and clear thinking. One approach to the problem, which has been found very satisfactory, is through elimination of the proportion formula and substitution of the following reasoning. If 65.5 grams of zinc liberates 2 grams of hydrogen, 1 gram of zinc will liberate 2/65.4 grams of hydrogen; accordingly, 20 grams of zinc will liberate 20 times as much as 1 gram does, or $20 \times (2/65.4)$ grams of hydrogen. This expression is identical with that obtained through the correct use of the proportion formula. Similar and other approaches might very well be made to the solution of a number of arithmetical calculations. It is absolute hypocrisy to assume that the mere solving of a calculation by a student necessarily means that he is fully aware of the principles involved. Calculations are indeed very poor substitutes for clear thinking.

Many students, on the other hand, appear to be completely lost when numbers and calculations face them; they are "number-shy," so to speak. They may have a good, or at least a fair, understanding of the principles of the subject, but are completely at a loss to interpret or apply these principles in terms of numbers. This situation is not rarely encountered but it is certainly not as common as the case cited above.

Undoubtedly, the most serious problem confronting teachers in the elementary chemistry courses today is one which deals with laboratory experiments and instruction. Laboratory training in these courses, especially general chemistry and qualitative analysis, is rightfully "on the spot." It is claimed by some that the results obtained in the laboratory do not warrant the relatively large amount of time spent by the student. In addition, the cost of apparatus and instruc-

tion for laboratory work is comparatively high. It has been suggested that lecture demonstrations before a class or small groups of students will serve the purpose in a satisfactory manner. The objections to such procedure are obvious. The entire problem has been clearly discussed by Schlesinger, in a paper already cited,[1] in which he points out what the objectives of laboratory courses should be. He says:

"In conclusion, let me repeat that, in planning laboratory courses, it is essential to keep in sight the major objectives—training in observation, in thought, and in action. Although the illustration of principles and the clarification of difficulties by direct contact with phenomena cannot be neglected, the main purpose must be achieved by selecting as the most significant part of the laboratory work, exercises the results of which the student cannot readily predict. These exercises should, as far as possible, demand the solution of some simple problem by experimental means. Successful work should require increasing accuracy of observation, increasing ability to use data and knowledge in drawing conclusions, and increasing independence in planning tests to check the conclusions drawn."

If the laboratory training can be carried out with these objectives in mind, there is no doubt but that it will not only be a distinctive contribution to the success of the course as a whole, but that it will also create an atmosphere of interest and enthusiasm for the student. The student will be encouraged to do some thinking for himself rather than merely follow printed directions.

At the University of Chicago we have been working for about two years in an effort to devise laboratory experiments for both the general chemistry and qualitative analysis courses with these objectives in view. It now appears that such experiments can be devised; however, the process is an exceedingly slow one. It will take coöperative effort on the part of many teachers to accomplish the desired goal. Since the problem is undoubtedly the most serious one confronting the teachers of the elementary chemistry courses today, it is essential that definite steps be taken to solve it.

A NEW RECORD FORM FOR QUALITATIVE ANALYSIS

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A STUDENT in qualitative analysis usually records his results in a series of equations or in the form of a chart similar to that used in the text as a tabulated set of directions for group analysis.

The equation method emphasizes the mechanics of equation writing more than it emphasizes the recording and interpretation of the phenomena observed. The chart form may require the recording of observed results together with their interpretation, but has the disadvantage of being unsuitable for printing as a standardized blank form for general use with all groups.

The record form reproduced herewith is free from these objections, and has been used in the author's classes for several years. It is printed and distributed to the students for use in connection with all groups of the ordinary scheme of qualitative analysis.

It will be noted from the directions at the top of the form and from the notes which have been added by the student in recording the step-by-step analysis of an unknown for Group I, that this blank provides space for brief descriptions of the materials and results of each significant procedure and that it requires the listing of the reagents and processes employed. Its graphic character helps the student avoid confusing his various precipitates and filtrates; and it helps the laboratory instructor, not only by enabling him to recognize quickly the exact place in the analytical scheme at which a student may be working, but it also frequently enables the instructor, in checking an erroneous analysis, to find the exact step at which the student deviated from the standard procedure.

This blank form is suitable for the preliminary analysis of a "known" as well as for the analysis of an "unknown." It is our custom to insist that the record be made out by the student as the analysis proceeds and that it be handed in at the end of the analysis. These reports are graded promptly and returned to the student, to become a part of his notebook.

EVIDENCE *for the* COMPLETE DISSOCIATION *of* SALTS *at* ALL CONCENTRATIONS *in* AQUEOUS SOLUTIONS*

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THE classical theory of electrolytic dissociation due to Arrhenius postulates that on solution in water electrolytes dissociate into positively and negatively charged ions. The extent to which this dissociation takes place depends on the nature of the electrolyte concerned. Dissociation occurs by the mere act of solution and does not require the application of an external electric field. It is also assumed that the resultant ions are mutually independent of one another.

Therefore, in the aqueous solution of an electrolyte we have (1) undissociated molecules, and (2) oppositely charged but mutually independent ions, the total positive charge of which is equal to the total negative charge. Furthermore (1) and (2) are in a state of dynamic equilibrium, so that

$$\text{undissociated molecules} \rightleftarrows \text{cation (or cations)} + \text{anion (or anions)}$$

Application of the rule of Le Chatelier to this equilibrium equation indicates that dilution should result in a shift of the equilibrium to the right (*i. e.*, dissociation should increase) and, conversely, concentration should effect a shift toward the left (*i. e.*, dissociation should decrease). The quantitative expression of this behavior is given by the well-known Dilution Law of Ostwald (*i. e.*, for a binary electrolyte $\frac{\alpha^2}{(1-\alpha)V} = K$, where V is the volume of solution containing 1 gram mole of the electrolyte, α is the degree of dissociation, and K is a constant), which is derived by applying the law of mass action to this equilibrium.

Qualitatively we know that the results of experiment are in harmony with the Arrhenius theory and with Ostwald's dilution law. The usual methods for the measurement of degree of dissociation (namely, freezing point, boiling point, vapor pressure, osmotic pressure, and conductivity methods) indicate that degree of dissociation does increase with increasing dilution. In fact, for so-called weak electrolytes in dilute solutions such measurements are in fairly satisfactory *quantitative* agreement with the demands of the classical conception. In the case of strong electrolytes, however, such quantitative agreement no longer exists.

That this should occasion no surprise is evident from an examination of one of the important postulates of the original theory, namely, that the ions, although of opposite electrical charges, behave as mutually independent particles in the solution. It is obvious that in the case of highly dissociated (strong) electrolytes, when a relatively large number of ions is involved, the distances apart of the ions cannot be very great, particularly in concentrated solutions, so that forces of interionic attraction must come into play. On the other hand, in solutions of weak electrolytes, and particularly in dilute solutions, interionic distances are greater, and the effect of interionic attraction must be less, and may be negligible. The classical theory, therefore, may be expected to hold for weak electrolytes (at least in dilute solutions) but it is not surprising to find that it breaks down in those cases where forces of interionic attraction may conceivably be appreciable.

For some years, and particularly since 1923, serious attempts have been made, notably by Debye, Hückel, and Onsager, to attack the problem of the "anomalous behavior" of strong electrolytes from a viewpoint different from that of the original Arrhenius theory. Starting with the assumption that strong electrolytes are completely ionized at all concentrations, the new theory of interionic attraction endeavors to explain the behavior of strong electrolytes quantitatively in terms of the mutual interaction of oppositely charged ions. In its present mathematical form the theory can only be applied safely to dilute solutions but in this field it has been so successful as to leave little doubt of its essential validity and of that of the assumption of complete ionization on which it is based. Indeed, so much faith has been placed in this theory that the more advanced textbooks on general chemistry now present the subject of strong electrolytes from the point of view of complete ionization at all concentrations.

Since practically all salts, with the exception of a few such as mercuric nitrate, chloride, and cyanide, and some containing cadmium, are commonly classified as "strong" electrolytes the idea of complete ionization has somewhat simplified the teaching of those ionic phenomena wherein salts are involved. For example, in the case of a saturated solution of a salt it is no longer necessary to write down, or even to imply, the second stage in the sequence

* Based upon a lecture delivered in the High School of Montreal on October 4, 1935, to the Mathematics and Science Section at the Seventy-first Annual Convention of the Provincial Association of Protestant Teachers of Quebec.

$$\underset{\text{(solid)}}{\text{salt}} \rightleftarrows \underset{\text{(dissolved)}}{\text{salt}} \rightleftarrows \text{cations} + \text{anions}$$

Similarly in precipitation reactions (*e. g.*, $AgNO_3 + NaCl \rightleftarrows NaNO_3 + AgCl\downarrow$) we can express the formulas in the ionic form without any mental or verbal reservations regarding the presence of salt molecules in the solution (*e. g.*,

$$Ag^+ + NO_3^- + Na^+ + Cl^- \rightleftarrows Na^+ + NO_3^- + AgCl\downarrow, \text{ or, } Ag^+ + Cl^- \rightleftarrows AgCl\downarrow).$$

It is of very real assistance in dealing with such ionic equations before a class to be able to say: "This is a salt. It is completely ionized in solution. Therefore, we represent it in the equation solely in the form of its constituent ions."

As a matter of fact, of course, there is nothing new in the omission of the formulas for undissociated molecules from ionic equations involving strong electrolytes. This has been done for years but very often with the reservation that *if* the solution is dilute the strong electrolyte *may* be considered as *practically* 100% ionized and so *may* be represented in the equation by its ions. As will be shown later such a reservation, potentially distracting or confusing to the elementary student, probably should now be omitted whenever most salts are under discussion.

The chief difficulties encountered in the interpretation of the experimental results obtained in studies of degree of dissociation or ionization and in explaining the physical properties of electrolytic solutions are due to our lack of knowledge regarding the behavior of oppositely charged ions in more or less close proximity to one another in aqueous solution. It is of interest, therefore, to see if there are any experimental data independent of assumptions regarding the nature, magnitude, and mode of operation of forces of interionic attraction which may throw light on the subject.

A certain amount of circumstantial information is available from studies of the crystal structure of salts by the methods of X-ray analysis. Whenever a narrow, sharply defined beam of X-rays passes through a crystal the electrons in the atoms of which it is composed are disturbed and this disturbance results in the emission of secondary sets of waves. Due to the regularity of the mutual arrangement of the units in a crystal these secondary waves undergo interference. The crystal, therefore, behaves like a three-dimensional diffraction grating toward X-rays. The relative arrangement of the atoms in the crystal is deduced from a study of the observed diffraction effects and in many cases information may be obtained regarding the electronic distribution in the atoms.

It has been found that most salts undoubtedly belong to an ionic (heteropolar) type in which the atoms or groups of atoms are present in the crystal as monatomic or polyatomic *ions*. The ions are separated by spaces in which the electron density is very small, and the electrostatic forces of attraction which hold the crystal together equally affect all neighboring ions in all directions. In the case of crystals containing a polyatomic ion (*e. g.*, NH_4, NO_3, SO_4, CO_3, etc.) the complex behaves as a single ion with essentially the same shape and size in all salts in which the particular ion concerned is contained.

The fact, therefore, that the crystals of a salt are built up usually by the orderly packing together of ions and not atoms immediately suggests that a salt must dissolve directly as ions. This argument is in fact frequently cited as supporting the idea that strong electrolytes are completely dissociated at all concentrations. The usual illustration offered is that of NaCl, the structure of which was one of the first to be elucidated by X-ray methods of analysis and which has been subjected to perhaps more X-ray investigations than any other. There is now no doubt that the sodium and chlorine exists as Na^+ and Cl^-, respectively, in the sodium chloride crystal. Furthermore, there is no vestige or suggestion of an NaCl complex or molecule in the structure. Each Na^+ is symmetrically surrounded by six Cl^-, and each Cl^- is surrounded by six Na^+.

Although the mutual arrangement of the ions in most of the typically ionic crystals (*i. e.*, those characterized as transparent or translucent non-conductors, or very poor conductors, of electricity) depends on such factors as the relative numbers, relative sizes, and polarization properties of the ions concerned, the ionic character of the building units and the absence of any apparent molecular complex is common to all. Most salts, therefore, are completely *ionized* even in the solid state. It does not follow, however, that they must in consequence be completely *dissociated* in solution.

When a salt crystal dissolves in water the regular, rigid, mutual arrangement of its constituent ions is destroyed (*i. e.*, the crystal as such disappears). When the ions leave the surface of the crystal during the act of solution they may (1) remain as separate (although not necessarily independent) entities in the solution, or (2) form more or less loosely bound complexes each containing equal numbers of positive and negative charges bound together by electrostatic forces and thus acting essentially as single (neutral) particles, or (3) enter the solution, some as individual ions, and some as neutral complexes. In all cases the salt is *completely ionized*. In (1) it would be *completely dissociated*. In (3) it would be *partially dissociated*. Alternative (2) is highly improbable and is not in harmony with experimental facts (*e. g.*, electrical conductivity).

This is as far as the circumstantial X-ray evidence on the structure of crystals can take us. Unfortunately, the interpretation of the X-ray diffraction effects from solutions is complicated by a number of factors, so that no reliable information on the dissociation of electrolytes is at present available from this source.

There is, however, another line of attack from which a few significant data already have been obtained and which promises to throw more light on the problem in the future. This is the systematic study of the Raman

effect in solutions of strong electrolytes at different concentrations.

If monochromatic light of a definite known frequency is incident upon a substance and a photograph is obtained of the spectrum of the resultant scattered light it is found that not only does the scattered light consist of light of the original frequency but it also contains light of modified frequency. The differences between the incident and modified frequencies correspond to infra-red frequencies which are *characteristic* of the molecules present in the substance under examination. The modified (Raman) lines in the spectrum of the scattered light are thus characteristic of the atomic or ionic groupings and of their modes of combination. The intensity of a given Raman line is directly proportional to the total number of particles emitting light of that particular modified frequency.

As examples of the interesting information which is now being obtained from the study of the Raman effect in solutions of strong electrolytes the work of Rao (*1*) on solutions of nitric acid and that of Woodward and Horner (*2*) on sulfuric acid may be mentioned.

Rao (*1*) has found that the Raman lines due to HNO_3 molecules diminish in intensity, while those identified with the NO_3^- ion increase in intensity, with increasing dilution. From the relative intensities of the lines he has calculated the degree of dissociation of nitric acid over a large concentration range (65% to 9.7% acid).

Woodward and Horner (*2*) have followed the dissociation of 100% sulfuric acid with dilution and have showed that their results are in perfect harmony with the stepwise dissociation of H_2SO_4 (*i. e.*, $H_2SO_4 \rightleftarrows H^+ + HSO_4^-$ followed by $HSO_4^- \rightleftarrows H^+ SO_4=$).

It is also of particular interest to note that it appears from these studies that concentrated solutions of strong acids do contain undissociated molecules.

There have as yet been very few systematic studies of the Raman effect in salt solutions from the point of view of electrolytic dissociation and its variation with dilution. Those of Rao (*3*), Simons (*4*), and Woodward (*5*), however, promise important developments in this field.

Rao (*3*) has made a study of the nitrates of Li, Na, K, NH_4, Mg, Ca, Sr, Ba, and Pb and has come to the conclusion that all nitrates are completely dissociated at all concentrations. According to Rao,

"The sources of evidence for the hypothesis of complete dissociation of nitrates are the following:

"(1) All nitrates in solution give rise to exactly the same Raman line, though in the solid state they reveal different lines. This shows that the nature of the radical corresponding to this line is identical in all of them in the state of solution, which cannot be so unless they are completely dissociated.

"(2) Raman spectra even with saturated solutions of nitrates taken with very long exposures did not show any trace of additional lines which can be attributed to undissociated molecules.

"(3) In some nitrates containing water of crystallization, *e. g.*, magnesium and strontium, the external frequencies which are revealed by the solid state are entirely absent in solution. This indicates that the molecular aggregates are completely disrupted in solution.

"(4) Measurements of the variation of intensity of the 4226 λ line of sodium nitrate with concentration have revealed a direct proportionality between the two; this should occur only if the substance is completely dissociated even at high concentrations."

Simons (*4*) has made a comparative study of the Raman effect in aqueous solutions of the nitrates of Na, K, NH4, Ca, Pb, and Cd, of the sulfates of NH_4 and Cd, and of nitric and sulfuric acids, respectively. He has found no evidence for the presence of undissociated molecules in the salt solutions. His studies of the acids indicate increasing dissociation with dilution, with that of H_2SO_4 occurring in two stages. These results, therefore, are in agreement with those already quoted.

Woodward (*5*) has made an interesting comparative study of solutions of KCl, $HgCl_2$, KCN, and $Hg(CN)_2$. He has found that whereas dissociation is complete in solutions of KCl and KCN, it is not complete in solutions of $HgCl_2$ and $Hg(CN)_2$. This is of particular interest because the two latter salts are among the comparatively few which are normally classified as weak electrolytes.

From such data as these, therefore, the tentative conclusion may be reached that all strong electrolytes are completely ionized at all concentrations, that strong acids are not completely dissociated in concentrated solutions, and that those salts which are known to be strong electrolytes are completely dissociated at all concentrations. Present data are too meager to warrant any conclusions regarding the dissociation of strong alkalies in concentrated solutions.

The object of this paper has been to summarize in a general way the present status of the theory of electrolytic dissociation particularly in so far as aqueous solutions of salts are concerned. As mentioned previously the effect of interionic attraction and the complete ionization of strong electrolytes is now considered in a few of the more advanced chemistry texts designed for first-year university work, although in some cases rather apologetically. It would appear that the time has come when the modern interionic attraction theory should receive at least qualitative mention in all such texts. It should be made clear that the classical Arrhenius theory is adequate to take care of the cases of those electrolytes in the solutions of which forces of interionic attraction may reasonably be neglected, whereas it breaks down, or must be modified, when such forces become appreciable.

The experimental results which are at present being obtained from the study of the Raman effect in solutions hold promise of yielding further valuable information on the degree, and variation with concentration, of the dissociation of electrolytes. The future developments in this field should be followed very closely by all those engaged in the teaching of the theory of electrolytic dissociation.

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A LECTURE NOTEBOOK FOR FRESHMAN CHEMISTRY

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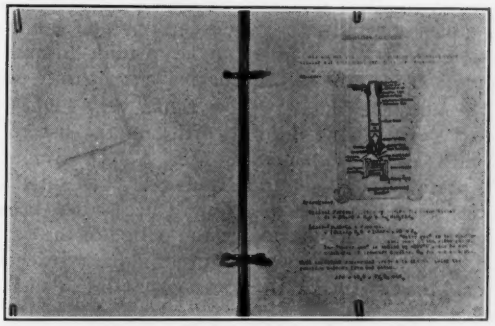
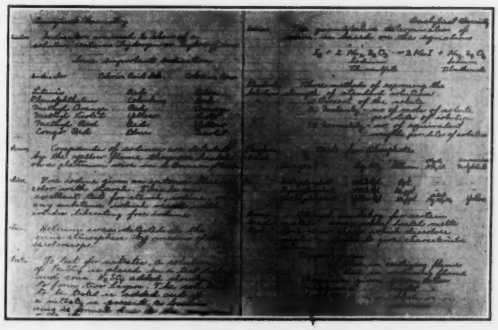
THE usual method of keeping a notebook by freshmen is more or less a record of notes taken during lectures, which gives a repetition of the subject matter in the same order as in the textbooks. The method proposed is to arrange the material given in the text and also the notes taken during lectures according to the following classifications:

1. History of chemistry.
2. Analytical chemistry.
3. Physical chemistry.
4. Industrial chemistry.
5. Minerals and ores.
6. Commercial uses of chemicals.
7. Physiological effects of chemicals.
8. Physical properties.
9. Chemical properties.

The photographs show how several students have kept their notebooks with respect to the above classifications. By arranging the material in this way, the students acquire a somewhat better foundation for future courses to be taken, such as history of chemistry, physical chemistry, etc. The notebook also affords the student an excellent method of reviewing for examinations, and at the same time learning to associate facts.



INDUSTRIAL PROCESSES



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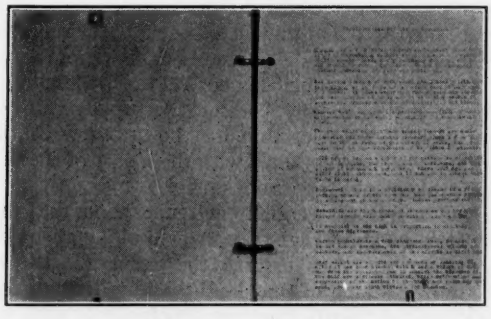
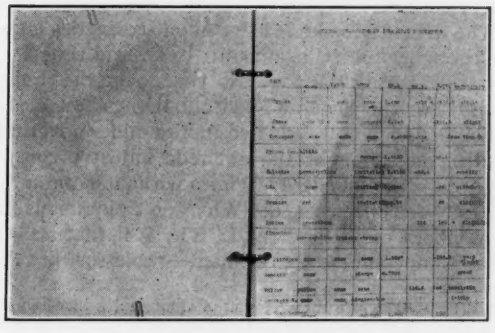


PHYSIOLOGICAL EFFECTS



PHYSICAL PROPERTIES

TRAINING *in* CHEMISTRY *for the* COSMETIC INDUSTRY*

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AS JUST part of a sentence in a paper presented before this Division (*1*), cosmetics, perfumes, and beauty culture were casually mentioned among ways and means of utilizing a chemical education. Since the publication of that paper, and almost entirely traceable to it, so many calls have come for specific information about the cosmetic industry that the notes assembled for talks to various groups and numerous long letters to individuals have readily formulated themselves into the subject matter of a separate paper.

The cosmetic industry now ranks very high (estimated variously as third to fifth) on the list of the nation's major industries. Mr. A. D. Whiteside (*2*), president of Dun and Bradstreet, has rated cosmetics second in a list of apparent necessities, because the drop in this industry over the period of the depression has been less than in any other industry excepting foods. It would seem, then, as if cosmetics should rank almost first among the new industries into which the vocational counselors are being advised by experts to direct their college-trained applicants for guidance (*3*); yet when the counselors seek the information to pass on to their applicants, they find that there is practically no formal training available to those that wish to prepare for a career in this industry.

During the spring of 1935, a survey was made within the New York metropolitan area to determine: (*a*) the demand for sound information on cosmetics; (*b*) how the demand is being met in the schools; (*c*) where and how such information would logically fit into a school schedule. Information was obtained from State and City Boards of Education; industrial and trade schools; academic schools on every educational level; numerous interviews with administrators and others in public health work, vocational guidance, and personnel placement.

The demand for knowledge about cosmetics is genuine enough; in fact, it amounts to an arid thirst! The agitation during the past two years over the proposed revision of the Federal Food and Drugs Act of 1906, which is designed to bring cosmetics under government control, has brought the cosmetic industry conspicuously into the limelight. Times without number have the questions been asked, "Why don't physicians know more about cosmetics?" and "Why is it that an otherwise competent—even brilliant—professor of chemistry can be so completely routed by a simple question on the composition and effects of cosmetics?" And in the answer to those two questions—in the profound ignorance and the monumental indifference which is enjoyed by most of the scientific and professional people—this investigator finds the principal reason for the exploitation of the cosmetic industry by both charlatans from within and self-appointed professional crusaders from without.

This indifference must be due to ignorance of what a cosmetic is. Vaguely, most academic people think of cosmetics as merely face creams or lurid make-up, associated with the vanity of woman. Down to the latest metamorphosis of the Copeland Bill, a cosmetic was defined as anything "intended for cleansing, altering the appearance of, or promoting the attractiveness of the person." Considering that this definition covers all tonics, dressings, dyes, bleaches, etc., for the hair; all creams, lotions, powders, and make-up for the face; depilatories, deodorants, anti-perspirants; dentifrices, mouth washes, manicure preparations; soaps, perfumes, and other aromatic materials, it will readily be seen that the term cosmetic is actually broad enough to comprise quantities of preparations used daily by millions of men and women. (Soaps have been exempted in the Copeland Bill, but for the purposes of this paper they will be included as an allied industry.)

A popular superstition is that physicians know all about these mysterious things that are used in the care of the skin and hair. This idea is popular even with physicians themselves, but it is a myth, which deserves to be exploded, once and for all.

In another paper presented before the Society (*4*, *5*), it was shown that cosmetic embellishment actually was an accepted integral part of medical practice for about five thousand years (3500 B.C.–1600 A.D.); but that the physicians dropped it as the knowledge of medical science increased and they had to devote their attention to the cure of bodily ills. Cosmetics, being presumably for the external embellishment of the well body, not the cure of the sick one, became so completely divorced from medical practice that for the next few centuries ethical physicians bothered with them only at the risk of their professional reputations.

Even in this more enlightened generation, the general practitioners know that they know nothing about these mysteries, but they assume the dermatologists take care of everything of that kind. Many dermatologists think so too, until they are confronted with some practical problem. Then they realize that while they

* Presented before the Division of Chemical Education at the 90th meeting of the American Chemical Society, San Francisco, California, August 21, 1935.

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were taught all they could absorb about the care of the skin in disease, they learned, in truth, practically nothing about the care of the skin (or of its appendages, the hair, nails, and glands) in health. With the exception of those physicians who have openly espoused the cause of physical education, most of the profession know little, if anything, of the care of the healthy body. Even the experts in public health know little of cosmetics, except as they come to unfavorable attention through occasional health hazards attendant on their use.

This being the situation, the logical group to which one turns next for information on cosmetics is the chemists, into whose hands these things fortunately came—only twenty-five to thirty years ago—after centuries of neglect and abuse. It was chemical research that started it, and it is the application of the principles and discoveries of modern chemistry that has brought cosmetics from the place of odds and ends which were approximately nowhere in 1906 to that of an enviably substantial and flourishing major industry (*6*).

The field covered by the cosmetic industry logically divides itself into three parts: (1) manufacturing and merchandising; (2) research in pure and applied science; (3) education and professional practice. Training in chemistry constitutes good groundwork for all of them but, as usual, the trained chemist must know more than chemistry; he or she must have versatility and ingenuity, and must rate high in personal equation.

The aforementioned survey in the educational field revealed that some information on cosmetics is given to the children in the lower schools for its subjective value in personal hygiene; but progressively, the schools and the courses become "the higher, the fewer." High-school students receive some further general instruction, in continued lessons on personal hygiene; but this is often presented in a rather hit-or-miss fashion by teachers of physical education, biology—whoever has the time and can assemble the notes. College students may escape it entirely unless they take a course in physiology, or special work in hygiene, where they are given many wholesome warnings about the harmfulness or uselessness of cosmetics, but practically nothing constructive or helpful for their personal living

As far as it has been possible to determine to date, courses in cosmetics are being given in a few widely scattered colleges of pharmacy: at Columbia University, New York, under Professor Curt P. Wimmer; at the Creighton University, Omaha, Nebraska, under Professor Charles W. Bauer; at Wayne University, Detroit, Michigan, under M. G. de Navarre; and at the State College of Washington, at Pullman, Washington, under Assistant Professor Belle Wenz. These courses offer, in the main, technical information, with the emphasis on the composition of recipes and the technic of compounding them. Professor John R. Sampey introduced some lectures on cosmetics into his course in pandemic chemistry, several years ago while he was at Howard College, Alabama. Dr. Sampey now gives this course at Furman University, Greenville, South Carolina; and it was extended to the Greenville Woman's College in the fall of 1935. The work is still given at Howard College; and at Alabama Polytechnic Institute, Auburn, Alabama, under Professor Roger Allen. On the postgraduate level, Professor Marston T. Bogert, of Columbia University, has directed the research problems for the doctorate of many students now prominent in the industry.*

The older the students, presumably, the more cosmetics they use. Obviously, they all will not be seeking a career in the cosmetic industry, but every man who shaves, grooms his hair, or worries about his incipient bald spots, as well as every woman who wants to look her best should be able to learn something about these things in some course in school. Occasionally, when the head of a department or a principal has been asked, "But why can't your teacher of chemistry or home economics give instruction of this kind?", the first response has been enthusiastic interest, as at the sudden dawning of a great idea; but too often this glow subsides just as suddenly, and the answer is, "I don't believe they could help us. They don't seem to know anything about cosmetics."

What a situation! All subjective considerations aside, when it is realized that cosmetics constitute the basis of one of the country's major industries, what a proof this exposes of that broad statement, too often heard from those in commerce and industry, that "the colleges do not keep pace with what is going on in the world!" Fortunately, in this case, the trouble lies not in the lack of knowledge of the science itself, but in the lack of direction in the application of the science. Every qualified teacher of chemistry in the higher schools has studied most of the basic science needed for the cosmetic industry. He has it now, in his head, in his reference library, or somewhere else equally accessible. All that is necessary is to sort it out, dust it off, and line it up in the proper order and perspective.

The standard major course in chemistry offers an excellent foundation: general inorganic and organic chemistry, qualitative and quantitative analysis, and physical chemistry. Among the usual electives, colloid chemistry, bacteriology, and chemical microscopy will be useful; and since all these cosmetic preparations are used on living human beings, physiological chemistry is essential; as are the supplementary sciences of biology—especially human physiology—hygiene, and physics (*7*).

The matter included in the usual course in organic chemistry must be supplemented by special study of those organic substances and compounds that enter into the composition of cosmetic products: oils, fats, waxes, glycerin, soaps and other detergents, dyes,

* Information from colleges in different parts of the country has been coming in so slowly that this may be considered as a progress report. The author will be grateful to anyone, anywhere, who can furnish the names of other colleges offering courses in cosmetics.

intermediates, lakes, perfume materials (natural and synthetic), and solvents. These, with the inorganic compounds that constitute the dry ingredients of powders, cover practically everything used in manufacture. For information on the compounding of preparations, some teachers may prefer to send their students to a college of pharmacy, but with the facilities that are at hand in every well-equipped department of chemistry, it would seem as if any teacher could assemble enough technical information for a good laboratory course in cosmetic chemistry which would give students practical experience both in the compounding of cosmetic preparations and in the methods of organic analysis required to take them apart.

Anyone who wishes to undertake experimental work on cosmetics must have full appreciation of the necessity for intelligent clinical research. In the compounding of preparations, the most important question is not "How do you make it?" but "What will it do?" And for the correct answer to that question, the serious research worker must know how to plan tests, conduct them under proper control, and interpret the results obtained. Again, because all these preparations are used on living persons, the student must know thoroughly the anatomy of the regions treated, dermatology (covering skin, hair, nails, and glands), and the principles of physiotherapy as used in massage.

The literature covering the vast field of cosmetics is almost appalling in its magnitude, but relatively little of it is of definite value. It can be divided into three groups, corresponding to the divisions in the industry: (1) trade publications, largely subsidized by manufacturers and advertisers, which, although many of them are of a much higher level now than formerly, are viewed with suspicion by the scientific investigators; (2) publications by medical authorities, textbooks on pharmacology, hygiene, etc., which, being based largely on "trouble cases," magnify the unfavorable aspects of the industry; (3) textbooks on cosmetology (for trade and industrial schools), bulletins of State or City Boards of Health or Education, in districts where beauty culture education and practice are controlled by law. In addition, there are innumerable books, pamphlets, etc., by lay writers, most of whom know only what they are told by those with something to sell; and an increasing number of books and bulletins by self-appointed professional crusaders.

In the face of all this, investigators have often had considerable difficulty in directing their study. With cosmetics a major industry, based on chemistry, *Chemical Abstracts*—that treasury of information on chemical science—offers little help. In other fields, *Chemical Abstracts* is better than a gold mine; the searcher merely turns to the section he seeks and there it is—the store of gold itself, refined from every known source of value. The searcher for information on cosmetics, however, must know exactly what he wants; and then he must enter on a laborious and often fruitless prospecting expedition, seeking his information under such scattered heads as *Chemical Industry, Fats, Water and Sanitation, Petroleum, Dyes and Textiles, Leather, Paints and Varnishes, Organic* and *Pharmaceutical Chemistry*, and several of the subsections under *Biological Chemistry*.* Much of what is found at all is useful only by analogy. It seems like a conspiracy—a clear case of "If you don't know what it's all about, you won't know what it's all about."

In the absence of formal textbooks on the subject teachers must assemble their own notes for lectures and laboratory work. Since many of the best reference books have never been translated, one should know both French and German. To supplement the available formularies, many valuable booklets can be obtained from the best manufacturers of raw materials; the only warning here is to learn to know these products by their chemical names as well as by their proprietary trade names.

Full credit must be given to the manufacturers of raw materials for the vast amount of research they have done in the development and utilization of new chemical discoveries in cosmetic products. Thanks to them, it is possible to say that "the greatest harm in cosmetics nowadays is not what the manufacturers put into their products, but what they say about them in their silly advertising." This rapid adoption of new products has not always been wise, however; for while the manufacturer of the raw material may be thinking first of "What will this make?", the manufacturer of cosmetic preparations for the consumer must think first of "What will this do?" That, after all, is what most concerns the purchaser. If the first manufacturer will not undertake the research for the necessary clinical knowledge, the second one must do so. Cosmetics are not merely commodities to be sold in quantities as great as possible; to the ultimate consumers they are "things for the thing signified"—beauty, or at least the means of making themselves a little better looking.

Any adequate treatment of the opportunities for employment in the cosmetic industry would be far beyond the scope of this paper. Briefly, though, it seems as if the best opportunities are in every part of the business and industry *but* the manufacturing just now. There are too many persons who know merely how to make cosmetics; but not nearly enough engaged in sound research, in intelligent selling, or in any phase of publicity and promotion; and especially not enough in teaching.

Most of the better manufacturers have good technical staffs, men and women with sound scientific training who direct research and production. All these houses have curtailed their staffs during the depression, but it is to these houses that the adequately trained young people may look for opportunities as conditions improve. These companies allow little for turnover in their employees; important and confidential work is never entrusted to beginners; and they distrust

* Beginning with the issues for January, 1936, *Chemical Abstracts* now devotes Section 17 (formerly *Pharmaceutical Chemistry*) to *Pharmaceuticals, Cosmetics, Perfumes*.—F. E. W.

"floaters" who just want to try them out to get a little experience.

The smaller manufacturers do need chemists, but they do not always know it. "Starting at the bottom" is impossible with these people because they want persons who already know how to make cosmetics. To many of these—some of them frankly "fly-by-nighters"—"research" means simply spending a day among the recipe books in the public library; "chemistry" is a mysterious, smelly business, implying the ability to analyze the other fellow's product and duplicate it; and "the chemist" is anyone who claims to have this ability, or someone who has a formula to sell, who may or may not also know how to mix the ingredients. In the lack of educational standards as to what a professional chemist is supposed to know and do in the cosmetic industry, many of these manufacturers themselves, and eventually the public, are duped by pseudo-scientists—ex-salesmen, ex-bottle-washers, ex-anybody who happens to have picked up the appropriate idiom.

As long as those who do the real research keep their records locked in their own archives, and as long as these problems are not brought openly into the college and university classrooms, laboratories, and clinics, this sad state of affairs will continue. The problems to be solved through the application of biochemistry to cosmetics can only be mentioned in a paper before this Division.* Determining the answer to only a few of them could well bring great glory to the discoverers, and the publication of such findings in reputable scientific journals would do far more to refute the absurd claims made for certain cosmetic products than can be accomplished by all past, present, and future tirades of the self-appointed crusaders and professional reformers.

The greatest need for information just now, and the best opportunities for the immediate future are in the educational and professional side of this work. Information on cosmetics—both the science and the art—should be available both to and from teachers in our academic schools, teachers of not only chemistry, but also physical education, physiology, hygiene, public health, home economics, sociology, etc., so that their students and the public may learn something of this vast field under proper educational auspices, instead of through the yellow press, the gossamer nothings of the advertisements, and the aforesaid publications of the professional reformers. It is through the educational circles that these agitators have been making their strongest appeal, even to the point of making this Society an instrument in their propaganda; and because the educators themselves know so little of the truth of the situation, or what answers to make, they have been at the mercy of such persons and groups.

Beautification has become big business in recent years and the indications are strong that it will be a good vocational outlet for some time to come. Chemists may have created the better products, which caused the increasing demand and the consequent decrease in the old prejudice against cosmetics, but the strongest factor in the enormous increase in the industry is the economic necessity for a good appearance in business. Forty-one states now have legislation governing the education and practice of those that work in beauty shops, and this branch holds many good opportunities for surplus teachers with training in the sciences. Here, in addition to pedagogy, one needs a practical knowledge of all the mechanical arts in the trade, plenty of sound social psychology, and, above all, *personality*. Such teachers must look as if they believe in their work, and actually practice what they preach. The Middle West and Far West (notably the state of California) (*8*) are far ahead of the East in the development of the educational and professional sides of the industry; and all State Boards find that trained and adaptable teachers are almost at a premium.

Much of what was said in the other paper (*1*) about utilizing a good chemical education in business and other industries, selling, writing, etc., applies specifically with great advantage to those chemists and teachers with particular knowledge of the cosmetic industry. Especially if the Copeland Bill is passed, but inevitably before long in any case, there will be the spontaneous generation of a demand all over this country for chemists that know about cosmetics. And with most of the necessary knowledge right within the possession of any faculty group, all we need are the catalysts—enterprising persons who will first stir everything up, then shake it all down, and formulate the pertinent information into courses suitable for various educational levels and objectives.

Dentistry, agriculture, and dietetics are only a few of the branches of science that have been codified and made respectable within comparatively recent times. Cosmetics should logically come next. For the vast amount of good there is in it, whether it is viewed from a scientific, economic, or sociological standpoint, the body of knowledge in the cosmetic industry—and the vast and vague "beauty industry" behind it—deserves to be codified, studied in our higher schools, and given the proper recognition as a worthy branch of applied science.

* A paper on cosmetics as a new field for research in biochemistry is available for the Division of Biological Chemistry.

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A TEST FOR VACUUM TIGHTNESS OF GLASS GRINDINGS

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WHENEVER glass stopcocks and joints or connections are to be sealed into evacuated systems it is desirable to be able to test their probable vacuum tightness in advance of use to be certain that poor grindings are not included. Below is described an arbitrary test that is simple, rapid, and reasonably conclusive. It is based on the rate of leakage of air through the dry, unlubricated grinding when under vacuum.

To perform the test the ground parts are separated and the ground surfaces thoroughly freed from lubricant by washing with ether or other solvent and rubbing with a clean, solvent-saturated cloth. When dry the parts are reassembled using *moderate* twisting pressure to assure contact. One end of the assembled apparatus is then inserted at *C* in an efficient water-pump or other vacuum system, provided with a simple manometer capable of reading vacua up to or above the vapor pressure of water, and a water trap, and having an approximately standard total volume. If the grinding to be tested is a stopcock, turn the plug to the maximum closed position; if a ground connecting tube, a piece of vacuum rubber tubing, the bore of which is covered with lubricant, is attached to the free end.

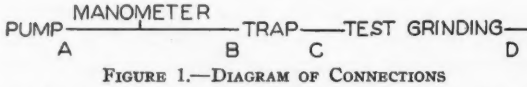

FIGURE 1.—DIAGRAM OF CONNECTIONS

A blank is first run on the tightness of the vacuum system alone, by closing the end of the trap line at *C*, evacuating until the manometer stands at 73 to 75 cm. vacuum, shutting off the pump from the system at *A* and allowing the closed system to stand for, say, fifteen minutes, and recording the drop in manometer reading. Air is then admitted to the system, the line at *C* is opened (if the test grinding is a glass connection the end at *D* is closed), and the operation is repeated. The difference in manometer drops noted between the test run and the blank is a measure of the tightness of the grinding. Some typical results are tabulated.

TABLE—VACUUM TIGHTNESS OF GLASS GRINDINGS

(Net pressure drops in 15 minutes in centimeters)

MANUFACTURER	STOPCOCKS			CONNECTION
	Straight-bore	*Slanting-bore*	*3-Way U Form*	
A	2.3	0.6	1.8	3.4*
	0.5		1.5	5.5
	1.4			
B	2.2			
	1.5			
	1.9			
C	2.6			
	14.3			
	4.3			
D			34.9	0.5
E				0 5

With a grinding of good quality it was possible to repeat test readings to within 2 mm.

On the basis of the data accumulated, stopcocks with net test values of more than 2.5, when clean and dry, may be found to be unsatisfactory for use in vacuum systems. Stopcocks showing values less than this and perhaps many showing losses of 2.5 to 5.0 cm. should, when properly lubricated, hold a vacuum indefinitely to within 0.1 mm. Similarly, with ground connections a test value of 5.0 cm. or less is considered to be satisfactory for vacuum work of this order when the ground surfaces are properly lubricated.

Attention should be called to the fact that the surfaces of fine grindings are delicate. It is easy to ruin the smoothness by roughly rotating the dry, unlubricated, finely ground faces against each other. Consequently, in fitting together the clean, dry parts for the performance of the test described above, every caution should be observed to make certain that the surfaces are free from grit, dust, or dirt of any kind and that only a *mild* twisting motion be used with no more pressure than necessary to assure contact.

A visual test of good grinding is easily made by drawing a line in water lengthwise of the clean dry grinding, putting the parts together, and turning slowly. The completeness with which the water film spreads over the grinding is an indication of the latter's excellence.

* This connection greased gave a value equal to the blank.

A PLAN *to* ELIMINATE *the* OVERLAPPING *in* HIGH-SCHOOL *and* COLLEGE SCIENCE COURSES*

FRED G. ANIBAL AND PHILIP A. LEIGHTON

Stanford University, California

THE relation between high-school and college science courses offers a perennial problem in chemical education. As is quite well known, with the "traditional" courses, for example, high-school chemistry based more or less on the College Entrance Examination Board requirements and the usual type of college freshman course, there is a wide variation in training and interests of those taking college chemistry. This, together with the fact that the average student has been found from experience to know little of the facts and principles of chemistry when he enters the college course, has resulted in a definite and apparently unavoidable overlapping of courses.

This overlapping is the result of attempting to achieve two different objectives by the same means. Out of each 100 graduating from high schools in the United States, at present about 35 enter higher institutions of learning.[1] Of these 35, less than 10 will indicate, as freshmen, a desire to specialize in those fields (such as chemistry, physics, geology, engineering, or medicine) where they have professional need of chemistry, physics, etc., and of these 10 only 2 will graduate in those fields. About 95% of our college freshmen, or 98% of our high-school graduates, then, eventually become non-scientific citizens in a world which is being revolutionized by science. As citizens in a society largely modified and controlled by scientific achievement, they become active consumers of science.

The scientific needs of this large majority of our high-school graduates or college freshmen who become consumers of science must not be neglected. Neither must the needs of the minority who need science professionally be neglected. It is the presence of these two groups in our courses which is chiefly responsible for the difficulties between high-school and college science. Efforts to modify the courses to meet the needs of both groups have resulted chiefly in meeting the needs of neither. Recognition of the need to separate the groups is showing its effect in the newer types of chemistry and physics courses that are being offered in the modern secondary school. Such courses as "Household Chemistry," "Shop Physics," "Practical Physics," "Everyday Chemistry," and the like, are rapidly making their appearance. These introductions, though steps in the right direction, are only half measures. Such courses tend to retain the traditional special science barriers and at the same time suit the demand of the school patrons for more functional science instruction. We must realize that most of our secondary school pupils require a more comprehensive training in general science than these courses can offer. Life's experiences are not classified into the restricted realms of the special sciences nor should training for adult activities be organized with the artificial barriers maintained to separate the fields of those special sciences.

In considering a program of science instruction for the secondary school which attempts to overcome the difficulties so far mentioned we are including that period in the educational development of the individual before he becomes intellectually independent and after he has mastered the fundamental processes commonly included in the first six grades. This concept of the secondary school will ordinarily embrace the three years now included in the junior high school, the three years in the present senior high school, and the two years of the junior college or the lower division of the university.

OBJECTIVES OF GENERAL SCIENCE COURSES

General science was introduced into the secondary school at the beginning of the present century[2] in response to the demand of the public for a more functional course in science for the non-scientist, and to provide an opportunity for boys and girls who leave school before graduation to receive at least some training in the simpler principles of sciences. This history of the general science course has been linked with that of the junior high school, since the objectives of both are identical. The rate at which courses in general science were introduced is remarkable. The period of most rapid growth was between 1910 and 1915 and by 1933 more than eighty per cent. of the schools of the United States were offering courses in general science.[3]

This rapid growth is evidence that general science is

* Presented before the Division of Chemical Education at the ninetieth meeting of the American Chemical Society, San Francisco, August 21, 1935.

[1] "Statistical summary of education," Bulletin No. 2, 1933, U. S. Department of the Interior.

[2] EIKENBERRY, W. L., "The teaching of general science," University of Chicago Press, p. 10.

[3] HUNTER, G. W., "Science sequence in the junior and senior high school," *Sch. Sci. Math.*, **33** (February, 1933).

more nearly meeting the needs of the general population of the secondary school than are the more specialized sciences. In spite of the stimulation given by general science courses and particularly in the face of a new culture based on scientific achievement there has been no increase in the percentage enrolment in the special sciences. A few have barely held their ground, largely due to the pressure of college entrance requirements, even though the colleges make little use of this training. There have been objections by the college departments of science that the general science courses are not scientific and do not properly prepare pupils for scientific pursuits. Such is not the purpose of this course nor should it be, in view of the very few who enter the field of science as a profession. The real objective of generalized science training at the junior-high-school level is to provide for our future citizens an "opportunity to acquire those scientific knowledges, skills, interests, and attitudes essential to intelligent behavior in a scientific age."[4] The popularity of a science offering of such a character with pupils, administrators, and especially the general public is clear evidence that it is meeting a felt need.

OBJECTIVES OF SCIENCE INSTRUCTION IN THE SENIOR HIGH SCHOOL

School patrons are demanding that school curricula recognize the changing needs of our high-school graduates, and offer courses in science which, by extending the generalized science instruction of the junior high school, will fit the pupil eventually to take an active part in a society modified and largely controlled by scientific achievement. The courses of the future are certain to cater to this demand and train primarily the non-scientist. When this development occurs, what of the pupil who will have professional need of specialized science training? Already the future chemists and physicists are losing valuable time when they are required to repeat beginning courses in chemistry and physics in the university with very little recognition given to the courses they may have taken in the high school. If these high-school courses are destined to become more general in nature even less recognition can be given to them in the university.

Under the ideal program which recognizes and attempts to meet the needs of both the scientific and non-scientific, or producer and consumer groups, we should be able to give science training to a great many more pupils than at present. At the same time we should avoid the repetition, the threshing of old straw, which is now a problem, and we should provide opportunity for the scientist to begin his specialized study as early as or even earlier than is possible under the present system. An organization which segregates the pupils into terminal and non-terminal groups should be avoided, and adequate provision should be made for the adjustment of pupils with changing interests.

If we offer courses truly designed to meet the needs of science consumers such training will attract the entire secondary population. Even the future scientist can profit by consumer science education since his future vocation will in all probability confine him between narrow limits within the whole field of science. In other areas than his particularly narrow field, then, the scientist becomes a consumer of science. These courses for the non-specialists will not be technical nor confined within the barriers limiting the special fields of sciences although it is essential that they be truly scientific. The objectives of such courses will be to train all the pupils to meet the ordinary problems of life in the same way that a scientist so successfully attacks the problems in his laboratory. It is imperative that training be in doing just this sort of thing. In the general training useful to the layman science content can be used as a means rather than an end. The problems which serve to stimulate this scientific activity on the part of the pupil must be drawn from life situations.

Courses in the senior high school, designed to train future educated laymen to appreciate and control the unspecialized scientific phases of their everyday environment, will be in line with modern trends of education for intelligent participation in a new social order. The secondary-school pupil is now being trained in an elementary-school system where unspecialized science has been an important feature of an integrated program. It should be the business of the secondary system to broaden this experience and to provide richer and deeper experiences in the field of unspecialized science. In a long-range program projected far into the future we might expect secondary-school science to be fused with the total offering in the high school. Such a program contemplates no barriers even between the traditional courses in all subjects. The various departments of the secondary school will perhaps lose their identity and courses will be set up in terms of the needs, interests, and level of intellectual growth of the pupils. Until that Utopian condition is actually in operation we have the social responsibility as teachers of science to move in that direction and begin at once by breaking down our own artificial barriers between the present specialized science offerings.

PROPOSED TYPE OF GENERALIZED SCIENCE COURSE IN SENIOR HIGH SCHOOL

At the present time the science work of the junior high school is fairly well established. General science is required in grades seven and eight and is elective in most school systems in the ninth. In the first two years of the senior high school, general courses in unspecialized science are proposed. At first these courses could be distinct from each other, one using content drawn from the living world, the other primarily intended to interpret the non-living natural science environment commonly referred to as the physical world. Either course may precede the other and may be taken in either the tenth or eleventh year of the senior high school.

[4] National Society for the Study of Education. Thirty-first Yearbook, Part I, "A program for teaching science," p. 194.

Our present course in elementary biology already tends to suit the objectives of this proposed course in the interpretation of the living world. Further refinement of this present course in terms of less technical content and with an aim to a more sympathetic appreciation of the living things which constitute our ordinary environment will result in a more functional and hence more suitable course for the non-scientific adult. Emphasis is to be placed on the functional rather than the structural aspects of plants and animals. An excellent beginning, however, has already been made, while little or no beginning has been attempted except in very rare instances to construct a course in the physical sciences at this level.

This proposed course in physical science to be offered in the tenth or eleventh grade of the senior high school is designed primarily to suit the needs of all the pupils in the secondary school. There will be no barriers between physics and chemistry, and both science areas will be drawn upon. In addition material will be taken from the restricted fields of astronomy, geology, physiography, meteorology, astrophysics, and any other science which may yield principles and methods of physical science helpful in the interpretation of both the immediate and remote non-living environment.* Of course it is absurd to attempt to cover this entire field within the scope of a one-year course, but we are assuming considerable early contact with this material in the elementary school and a still richer experience with these physical science principles in the seventh and eighth grades. Some of the pupils will have elected the ninth-grade science course and these, under certain conditions to be considered later, will be included in the large group of pupils enrolled in this unspecialized course in the physical sciences.

The proposed course in general physical science will have one primary objective but will suit the needs of three types of pupils. First and fundamentally this course will make use of the scientific phases of the physical environment to develop in all the pupils an appreciation of the functioning of science in our present civilization. Scientific method will be stressed and the pupil will have abundant practice in applying the method of the scientist to his own life problems, both in the classroom and in the laboratory. Specifically the large group of non-science majors will be served first by this course. Secondly, this general course, with emphasis on method, serves as a general overview of the special fields of physical science which is such an important part of the training of the science specialist. On this basis it will serve as preparation for higher-level courses in the special departments of the physical sciences. The third objective of the course will be that of providing the pupil who has a tendency to specialize very early in the biological sciences with proper foundation in the physical sciences.

* A program for generalized courses in physical and biological sciences for the senior high school is suggested in The Thirty-First Yearbook of the National Society for the Study of Education entitled, *A Program for Teaching Science*. See especially pages 7 to 9.

The objectives of the proposed course in general biological science will be similar to those suggested for the general physical science and will meet the requirements of three types of pupils in much the same way. The first type is the general pupil whose needs have been stated. This will comprise the group of those who take the course in general physical science. The two other groups are, first, the specialists in biology who use the training as an introduction to further study in biology, and, second, the exceptional pupils who want to specialize early in physical science and so often neglect to get a suitable overview of biological science.

For the large majority of high-school pupils these two general courses will be terminal, and by this offering they will be served far better than at present where only 7 per cent. take physics and 8 per cent. take chemistry.[5]

Obviously, very few indeed elect both chemistry and physics under our present system and even then these courses are now taught quite independently, and very little fusion is attempted by the instructors. The befuddled pupil actually differentiates between the gas laws in chemistry and the gas laws in physics.

SPECIALIZED SCIENCE COURSES FOR THE SENIOR HIGH SCHOOL

These two general courses will constitute the first-level science offerings in the senior high school. The second-level science courses, which may be offered in the larger high schools, will involve a more thorough and intense treatment of the special sciences than is possible under the present system. The pupil who takes the traditional course with no more conscious purpose than to use it for college entrance will receive entrance credit for the general or first-level courses and will not appear in the second-level courses.

Since it is expected that relatively few will elect these advanced courses, a wide variety of offerings will be possible, depending upon the needs of the pupils and the training and ability of the members of the science department of the particular school. Ordinarily courses in chemistry and physics will be offered in the field of physical science and courses in advanced biology and physiology in the field of the life sciences.

Two types of pupils will be admitted to these higher-level courses. Pupils who very early show aptitude in physical science will ordinarily elect the ninth-grade general science and can be counseled to take the general course in biology in order to balance their training in case they expect to elect both chemistry and physics. This group will be very highly specialized and will usually be so well adapted to the special field that they will not need the general physical science course since they will work both in the field of chemistry and physics and will become familiar with scientific method in the general biology course. Pupils who very early show aptitude in biological science will similarly be counseled

[5] HUNTER, G. W., "Science teaching," American Book Co., New York, p. 47.

to take the general physical science course properly to balance their training in the whole science field and may then be permitted to take the advanced courses in biological science.

The other type of pupil who enters the advanced courses in the special sciences will be the one who elects the special course through having been stimulated to an interest in pure science because of his contacts in the general courses. Ordinarily, this group will have taken both of the general courses previously and will be well able to do a creditable piece of work in some specialized field of science. In either of the two cases cited, the pupils who elect the advanced courses will have been naturally selected as embryo scientists. Those who thus tend to specialize early will be prepared for and will demand a course that can be designed to give them far better training for scientific vocations, for example, as chemists, physicists, doctors, or engineers, than either the present high-school course in chemistry or physics or even the general course in chemistry now offered in the first year of college, and required of non-science majors as well as beginning scientists.

The advanced courses here suggested are to be built upon a well-established program of science throughout the elementary school, the junior high school, and the first two years of the senior high school. Pupils who elect these courses in the special sciences will have been selected through the operation of their own interests and aptitudes. They are ready for prevocational training of a rather special character.

Such a course in technical chemistry will be limited to students who have previously shown distinct ability in the skills and intelligence needed to carry out a creditable piece of work. Since those who elect such a course in the senior year of the high school will have had previously at least four years of science training above the elementary school, and since this course is to be made a requirement for future science majors only and not a general college entrance requirement, the course may be of the same standard of excellence in the high school as in the college. Only the larger high schools will need to offer such a course, since so few of the graduates of the secondary school continue serious work in pure science or have professional need of that type of training. It is important to note, however, that pupils taking this course in the senior high school will enter directly the second level courses in chemistry in college and will thus begin their scientific careers a year earlier than at present.

GENERALIZED SCIENCE COURSES AT THE COLLEGE LEVEL

At present many beginning courses in chemistry in the college are meeting the same difficulty as the high-school courses in that they are required as part of the pattern for a degree for non-science as well as science majors, the two groups of students being thrown together in a single course. In all too many cases the majority of students in these courses are not sincerely interested in the work and consequently lack sufficient enthusiasm to profit from the instruction. Modifications have resulted in many instances, but in such modified courses we are not truly meeting the needs of either group, and especially are we allowing the future scientist to suffer in the effort to make the course suitable to the lawyer, the business executive, the historian, and other non-scientific vocations in the technical sense.

As in the high school, so in the college offerings we must not neglect the general scientific training of these non-science majors. For such groups it is suggested that, as in the senior high school, survey courses in physical science and in biological science be offered in the first two years of the college or university. Such courses are now being offered in a few such educational institutions as the University of Chicago, and Stanford; however, these courses are still in an experimental stage.* As in the high school, these survey courses can be organized to meet the needs of the non-science majors in a far more adequate manner than do the special science courses. The survey course in physical science must be flexible in organization and designed to interpret the world of physical phenomena as it actually exists. No artificial barriers between physics and chemistry, geology and astronomy must remain. The units of such a course must be drawn from the physical environment and not primarily from the special sciences. The work of the course consists of demonstration lectures, small discussion groups, and laboratory work for individuals and groups who desire a closer contact with typical phenomena of the physical world. Experience has shown that division of the course into periods of a certain number of weeks devoted to each of the special sciences has not been satisfactory. The history of the evolution of the present general science course in the high school might be enlightening on this feature of organization. Time could be saved in the organization of such a course since the general science course has passed successfully through many of the stages of evolution that have been causing difficulty in this more advanced general physical science course. The survey course in biological science bears exactly the same relation to the survey course in physical science in the college as the general biology course in the high school bears to the general physical science course at the lower level.

The students in the university who are to be admitted to these survey courses are largely the non-science majors. In general the pupil who enters from the high school with training only in the general courses in science will continue this type of contact with the world of science through the general survey courses. He will never contact the technical courses in the special sciences, much to his relief and general profit, and considerably to the advantage of the science major for whom the technical courses can now be definitely organized.

It might be desirable for the student specializing in physical science to pursue the general biological science course rather than the technical courses in

* HAVIGHURST, R. J., "Survey courses in the natural sciences," *Am. Phys. Teacher*, **3**, 97–101 (Sept., 1935).

the life sciences which under our present system he is many times required to complete. It is to be noted, however, that at this higher level there will be cases where technical courses in both the physical sciences and the life sciences will be suited to the needs of the specialist. This is certainly true of the premedic group.

PROPOSED SEQUENCES FOR TYPICAL GROUPS

The sequence of courses in science throughout the period of secondary education has been suggested to meet the needs of various groups of pupils. The general nature of each of the courses was briefly justified in each case; perhaps in the way of a summary it might be well to consider the typical programs to be followed by several different types of pupils.

For the first two years all pupils will follow the same program, *i. e.*, general science in the seventh and eighth grades built upon a well-integrated program of elementary science in the first six grades of the elementary school. For some pupils the training of these eight years will constitute the whole extent of their science education. It provides, however, at least some training in the content and method of natural science whereas a decade ago little more than object teaching in nature study had been attempted.

Of the pupils who complete the junior high school, some will do the work of the elective science in the ninth year. For those who received no further formal education this course will be terminal and has been organized with this possibility in view. Of the pupils who enter the senior high school, some will have completed the elective science of the ninth grade and others will not. Presumably those who elected this ninth-grade general science were already exhibiting evidence of aptitude in the science field. If we analyze this group we will find a few who are leaning toward work in physical science and others who show a decided preference for biological science.

Those tending to specialize this early in the field of life sciences will pursue the work of the general physical sciences course the better to balance their training, and then be permitted to follow up their interests in either the general course in biology or the advanced courses in biology, if they desire to undertake the higher level courses. They will enter the university or junior college well able to continue their work in the biological sciences, and the further to broaden and deepen their experiences may elect the work of the general survey of physical science.

The pupils who give early promise of ability in physical science will first do the work of the general biological science. This training in biology will be followed either by the general physical science or the advanced courses in physics and chemistry. Entering the university this physical science group will continue their work in the technical science of their choice, entering the second-level courses in either physics or chemistry in case the first-level course has been successfully completed in high school. These physical science majors may, if time permits, pursue the work of the college survey course in biology the further to enrich and the better to balance their training.

The large majority that show no special science aptitude upon entering the senior high school will select either general biological science or general physical science whether or not they have completed the ninth-grade science, and will follow this with the other general course in the next year. For most students these courses will be terminal.

For those who enter college with training in the general courses only, the choice is open to begin specialization or to select the appropriate general survey course at the college level. Again the non-scientific majority will elect the latter type. It will be noted that the pupil may begin his specialization at any point beyond the junior high school, and is guided at all times toward the enrichment of that type of scientific knowledge which best meets his needs.

OVERLAPPING AVOIDED

Taking the courses in chemistry as an illustration, the pupil from the small high school where a special chemistry course is not offered, or the pupil from the large high school who did not elect this course and who now desires it, will take first-year chemistry in college. He will enter the college course with practically all the knowledge of chemistry which experience has shown can safely be assumed for the average pupil with the present high-school chemistry. Repetition will be reduced to a minimum and, moreover, he will have a concept of the meaning and importance of the scientific method and of the relation of chemistry to the other physical sciences and to life, which will sustain interest and assist him toward an ordered understanding of the subject matter. Entering, with these advantages, a course from which non-science majors have been eliminated and which is designed purely for those with vocational need of chemistry, he will advance just as rapidly as, if not more rapidly than, does the average science major in the college course which caters to both classes.

Since the second level course in chemistry in the high school should be equivalent in every way to the first-year course in college, the pupil who elects chemistry in high school will avoid overlapping in the same manner and will begin his professional training a year earlier than is possible at present. Analogous conditions should exist in the other specialized courses; physics, geology, biology, etc.

The problem of repetition of high-school material in the general physical science or general biological science courses in college will be no more important than is the problem of repetition of elementary school science in the junior high school, or of junior high-school science in the general courses in senior high school, since these courses are or should be offered not on the basis of content but on the basis of the intellectual level of the pupils.

CORRELATION WITH MODERN TRENDS IN SECONDARY EDUCATION

It is believed that the program proposed, besides greatly reducing the amount of repetition found under the present system, cares for the needs of both the scientist and non-scientist without making any obvious separation of pupils into terminal and non-terminal groups. It allows for a wide range of adjustment for those pupils with changing interests. Although it is not intended as the final program in any respect, it is in accord with the trends in secondary education, which indicate a fusing of all courses and departments in the senior and junior high schools. When this condition is realized, personality integration will be the goal of a general course of instruction based on the interests and needs of pupils here and now. Science is certain to be a very important area from which the pupils will select problems and activities for social growth. Meantime, it is believed the scope and sequence of the science offerings here proposed will more adequately meet the demands of a socially centered secondary school, and will contribute more richly than can the present system to the development of a wholesomely integrated personality.

SOME USES FOR MODELING CLAY IN THE CHEMICAL LABORATORY

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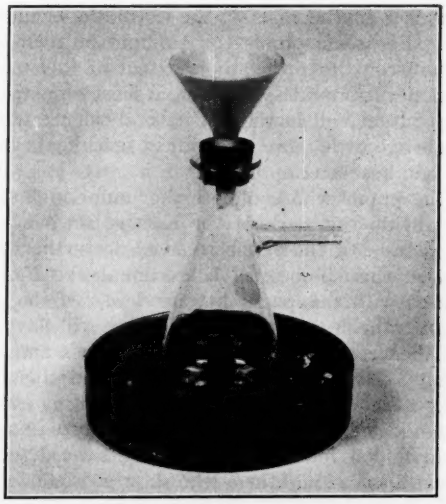
WHILE modeling clay finds frequent use in a biological laboratory for sealing anaërobic jars and Petrie plates or for holding tubes, it is seldom encountered in a chemical laboratory. An account of some of the uses which chemists may make of the rather unique properties of this material therefore appears worth while.

The most obvious use of modeling clay is in the making of models. From a number of balls of modeling clay and some matches simple atomic or molecular models can easily be constructed. Models of the energy levels of reactions for use in the study of quantum mechanics can conveniently be fashioned from this material. Models of the various crystal forms may be made, a process which may be useful in instruction.

A use taken from the experience of the biological laboratory is the sealing of flasks and vials with modeling clay. Although the clay is relatively impervious to water, it is partially dissolved by many of the common organic solvents, with the result that it cannot long be used to confine organic vapors. It can nevertheless be used successfully in forming a temporary seal. This is particularly satisfactory in closing ampoules to which the section cut from the stem can be fitted tightly and held in place by modeling clay.

Since the clay is fairly heavy (d. 1.6), it can be used in the form of rings to hold small vessels upright in water or ice baths. Because the material rapidly loses its coherence at higher temperatures most of its uses are limited to temperatures below 50°C.

Uses of modeling clay which depend on the ability of the material to adhere to dry glass are of special interest to the chemist. A small pan of clay will hold upright the small filtering flasks which without support frequently tend to overturn in the midst of a filtration. As the accompanying photograph shows, this arrangement is remarkable for its simplicity and convenience. By giving the flask a quick pressure toward one side the vessel can readily be removed, emptied, and set up again by pressing it against the plate with a twisting motion, all in a fraction of the time required to operate a clamp. By occasionally exposing fresh surfaces of clay and by keeping the material and the exterior of the flasks free from solvents and moisture, the support furnished by this device is practically as reliable as that provided by a stand and clamp. If by accident either the clay or the exterior of the vessel is wet by water or solvents, the surfaces of both should be carefully dried before the plate is used again. The clay gradually hardens, and after about a year of use should be replaced.



USE OF MODELING CLAY AS SUPPORT FOR FILTER FLASK

The clay-containing plate can also be used for holding round-bottomed vessels over a wide range of shapes and sizes. Care should be taken, however, that the downward projection of the center of gravity of the vessel falls within or near the area in contact with the clay, for if this condition is not fulfilled a heavy vessel may gradually pull loose from the plate. When modeling clay is once introduced into the laboratory, a multitude of new uses will undoubtedly be discovered.

The USE *of* SODIUM PARAPERIODATE *for the* DETECTION *of* MANGANESE *in the* ELEMENTARY QUALITATIVE COURSE*

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RECENTLY Thompson and Wilson[1] have reported in considerable detail results obtained from a quantitative determination of manganese in sea water, in which case the manganese was oxidized to permanganate by means of an alkali periodate according to the method of Willard and Greathouse.[2] According to Willard and Greathouse the chemical reaction is

$$2Mn(NO_3)_2 + 5KIO_4 + 3H_2O \longrightarrow 2HMNO_4 + 5KIO_3 + 4HNO_3$$

and success depends upon a sufficient concentration of acid to prevent the occurrence of a precipitate, in which case a stable solution is obtained in which the color will remain for months.

It has been found possible to adapt this method of oxidizing manganese to the development of an excellent qualitative test for manganese which can be used efficiently in the first course in beginning qualitative analysis.

Gutzeit[3] has mentioned the possibility of using periodates for a qualitative test for manganese. Also, Tillmans and Mildner[4] have suggested the possible use of a mixture of potassium periodate, acetic acid, and "tetramethyl base" for a qualitative test for manganese.

After the precipitation of the ammonium sulfide group in the usual way, and separation of the manganese from NiS and CoS by treatment with dilute hydrochloric acid, the periodate test for manganese may be made according to the following procedure.

Take up on the end of a stirring rod a small amount of the washed precipitate resulting from the NaOH and Na_2O_2 treatment. Place the precipitate in the bottom of a test-tube and dissolve in 2 cc. of concentrated sulfuric acid. This can be done conveniently by standing the rod in the test-tube and pouring the acid over it. Pour this solution out (do not allow time for draining) and use the small amount (about $\frac{1}{2}$ cc.) remaining in the tube for making the test. Cool the tube, add 5 to 10 cc. of the sodium paraperiodate reagent (1.2 grams of sodium paraperiodate and 60 cc. of manganese-free concentrated sulfuric acid per liter of aqueous solution) and heat almost to boiling (a gentle agitation or "bump" can be felt if the test-tube is being held in the hand). The pink color of the permanganate develops slowly and is quite stable. Care must be exercised not to take too much of the hydrated manganese dioxide in the beginning since this is the most likely source of error.

The trisodium paraperiodate used for making these tests was readily prepared by bubbling chlorine into a solution of sodium iodate in sodium hydroxide.[5] A good yield of trisodium-paraperiodate of high purity was readily obtained. Sodium paraperiodate can now be purchased from a few chemical supply houses.

Several manganese sulfate solutions of varying concentrations were tested for manganese by means of periodate according to the above-described procedure, 25-cc. portions being used in each case. A solution containing 2 mg. of manganese per liter did not yield a noticeable precipitate with sodium peroxide. A solution containing 5 mg. of manganese per liter gave a precipitate with sodium peroxide but a sufficient amount could not be removed from the paper to give a positive test. A solution containing 10 mg. of manganese per liter gave a positive test. A 25-cc. portion of the usual qualitative unknown will contain perhaps a hundred times this amount of manganese. Thompson and Wilson[6] report that it is possible, by the use of periodate, to detect variations of 0.001 mg. of manganese in one kilo of sea water. This sensitivity is of the order of 10,000 times as great as that of the qualitative test reported above. Such great sensitivity would of course be unsuited to the beginning course, since manganese might be found as an impurity in practically all unknowns.

During the last semester of the past school year three beginning classes at St. Louis University were

* Presented before the Division of Chemical Education at the 90th meeting of the American Chemical Society, San Francisco, August, 1935.

[1] THOMPSON AND WILSON, *J. Am. Chem. Soc.*, **57**, 233 (1935).
[2] WILLARD AND GREATHOUSE, *ibid.*, **39**, 2366 (1917).
[3] G. GUTZEIT, *Helv. Chim. Acta*, **12**, 713 (1929).
[4] TILLMANS AND MILDNER, *J. Gasbel.*, **57**, 496, 523, 544 (1914).
[5] A. C. HILL, *J. Am. Chem. Soc.*, **50**, 2678 (1928).
[6] THOMPSON AND WILSON, *ibid.*, **57**, 233 (1935).

asked to use the above-described periodate test for the qualitative detection of manganese. One class (a class of thirty-two girls at Fontbonne College of St. Louis University) without experience in qualitative analysis was first instructed in the methods of the test and then given unknowns which contained either manganese or iron or both. The mixture was precipitated with NaOH and Na_2O_2, and the resulting precipitate was tested for manganese. The work was closely supervised, and all thirty-two unknowns were reported correctly. The results obtained are tabulated in Table 1.

TABLE 1

RESULTS OF PERIODATE TEST AS REPORTED BY A BEGINNING CLASS AT FONTBONNE COLLEGE OF ST. LOUIS UNIVERSITY

Composition of Unknown	*No. of Unknowns Issued*	*Students' Report on* Mn^{++}
Manganese alone	18	18 positive tests for manganese
Iron alone	4	4 negative tests for manganese
Iron and manganese present	10	10 positive tests for manganese

In the case of two other groups in qualitative analysis, consisting principally of boys (one class of arts and science students and the other of premedical students—approximately 90 in all), the results obtained from the analysis of one hundred forty unknowns of varying complexities were carefully recorded. Of the one hundred forty unknowns, forty-one contained manganese and ninety-nine did not. The composition for each unknown containing manganese is shown in Table 2. As is to be seen from the table a total of five mistakes out of forty-one unknowns was made. (Each of the unknowns listed in Table 2 was used about three times.) In the case of unknown No. 12 the hydrated manganese had not been thrown out at the time of inspection and the laboratory instructor got a positive test for manganese on the first effort. There does not seem to be anything peculiar to the composition of the four unknowns in which manganese was missed. The authors are inclined to believe the results are as good as could be expected from a group of beginning students.

TABLE 2

RESULTS OF PERIODATE TESTS MADE ON GENERAL UNKNOWNS CONTAINING MANGANESE

No.	*Composition of Unknown*	*Report of Tests*	*Remarks*
1	Mn^{++}-Co^{++}-Cr^{+++}-K^+	All positive	Groups II and IV missing
2	Mn^{++}-MHg^{++}-Cd^{++}-Cr^{+++}-Mg^{++}-NH_4^+	All positive	No Group IV
3	Mn^{++}-Fe^{+++}-Cu^{++}-Ba^{++}-Na^+	All positive	Groups II–V present
4	Mn^{++}-Hg^{++}-Fe^{+++}-Sr^{++}-Na^+	All positive	Groups II–V present
5	Mn^{++}-Cu^{++}-Co^{++}-Al^{+++}-Zn^{++}-Ca^{++}-K	All positive	Groups II–V present
6	Mn^{++}-Pb^{++}-Cd^{++}-Ba^{++}-Na^+	All positive	No Group III except for Mn
7	Mn^{++}-As^{+++}-Ni^{++}-Zn^{++}-K^+	All positive	No Group IV
8	Mn^{++}-Pb^{++}-Cu^{+++}-Bi^{+++}-Cd^{++}-Ca^{++}-Na^+	All positive	No Group III except for Mn
9	Mn^{++}-Hg^{++}-Cu^{++}-Cr^{+++}-Mg^{++}-NH_4^+	All positive	No Group II except for Mn
10	Mn^{++}-Cd^{++}-Ba^{++}-Na^+	All positive	Groups II–V present
11	Mn^{++}-Cu^{++}-Co^{++}-Al^{+++}-Zn^{++}-Ca^{++}-Na^+	2 negative	Both students above avge.
12	Mn^{++}-Cu^{++}-Ni^{++}-Co^{++}-Cr^{+++}-Ca^{++}-Mg^{++}	1 negative	Instructor got a positive test
13	Mn^{++}-Bi^{+++}-Ni^{++}-Al^{+++}-Cr^{+++}-Ca^{++}-K^+	1 negative	Avge. student
14	Mn^{++}-Pb^{++}-Ni^{++}-Co^{++}-Zn^{++}-Ca^{++}-K^+	1 negative	Student above avge.

Table 3 shows the composition of four unknowns which did not contain manganese but for which manganese was reported as present. A total of forty-five such unknowns was issued and ninety-one results were checked; *i. e.*, each unknown was used, on the average, about twice. Only the five mistakes shown in Table 3 were reported. Because of the great sensitivity of the paraperiodate test it was naturally suspected that manganese might in reality be present in these unknowns as impurities. In the case of unknown No. 2 a large amount of the student's precipitate seemed to give a positive manganese test. Of the forty-one other unknowns not containing manganese which are not reported in Table 3, six contained Bi^{+++}, twelve contained Fe^{++} or Fe^{+++}, twelve contained Zn^{++}, three contained Ba^{++}, and thirteen contained Na^+. In none of these cases was a positive manganese test reported. It, therefore, does not seem probable that the erroneous manganese report can be explained on the basis of impurity unless that impurity was introduced by the student himself. Unknowns Nos. 1, 3, and 4 were examined carefully for manganese, following the procedure described above. In no case was a positive manganese test obtained. In the case of unknown No. 1 a slight pink color was obtained, due to a small amount of cobalt having dissolved in the dilute hydrochloric acid. Although this color is by no means identical with the permanganate color it possibly accounts for the student's positive manganese test. When the small amount of cobalt that had been taken into solution by the dilute hydrochloric acid was removed by a second sulfide precipitation no pink color was obtained. Seven other cobalt-containing unknowns which did not contain manganese were issued, and in no case was a positive test reported.

TABLE 3

SHOWING COMPOSITION OF UNKNOWNS FOR WHICH POSITIVE MANGANESE TESTS WERE REPORTED BUT WHICH DID NOT CONTAIN MANGANESE

No.	*Composition of Unknown*	*No. of Incorrect Reports*	*Remarks*
1	Co^{++}-Mg^{++}-Na^+	1	Avge. student
2	Bi^{+++}-Fe^{+++}-Zn^{++}-Ba^{++}-Na^+	1	Student below avge.
3	Ni^{++}-Co^{++}-Cr^{+++}-K^+-Na^+	2	One avge. and one poor student
4	Cu^{++}-NH_4^+-K^+	1	

In the case of unknown No. 3 a light green color developed when the sodium peroxide residue was dissolved in sulfuric acid which, however, was not sufficient to interfere seriously with the test, as could be demonstrated by adding a small amount of permanganate to part of the solution as a control.

It is quite clear that this simple test in no way interferes with any other manganese tests that seem desirable, since for the most part other tests are made on the same hydrated precipitate required for this test,

the most common ones being the Na_2CO_3-$KClO_3$ bead test and the HNO_3–PbO_2 test. Either of these tests are known to be quite reliable in the hands of experienced chemists but leave much to be desired in the hands of beginners. The periodate test for manganese as described above appears to give great promise of being a satisfactory manganese test that can be used by the beginning student in qualitative.

SUMMARY

The method of Willard and Greathouse for oxidizing manganese to permanganate by means of sodium paraperiodate has been adapted to the beginning course in qualitative analysis.

The paraperiodate is easily prepared from materials available in any laboratory.

The test is very easily and accurately made as has been demonstrated by the use of a class untrained in the methods of qualitative analysis.

The test is successful when applied to unknowns containing a great variety of cations and anions.

Cobalt when present in an unknown in large amounts may interfere with the manganese test, in which case it must be removed by reprecipitation with hydrogen sulfide.

MODERN THEORIES OF ELECTROLYTES IN ELEMENTARY CHEMISTRY

IT WILL be noted that the program for the Pittsburgh meeting of the Division of Chemical Education includes a colloquium or round-table discussion of the teaching of modern theories of electrolytes and conceptions of acids, bases, and salts. For the benefit of those who attend this session, as well as for others who are interested in this live topic, the following bibliography has been compiled. This is not an attempt to cover the fundamental research in this field, but rather to list the general articles of an elementary nature which have appeared in THIS JOURNAL, and elsewhere, and which should help teachers of chemistry, particularly, to orient themselves in the vast maze of discussion which has been going on.

This is but one of many topics in general chemistry concerning which there has been a slow but persistent change of viewpoint, and many teachers would be glad to take advantage of such changes if they knew how to do so. Progress in chemical education has been repeatedly slowed down by the tendency to leave new and fundamental developments too long at the level of the graduate course. Atomic structure, isotopes, crystal analysis, etc., might well have appeared in our elementary textbooks long before they did. On the other hand, we must avoid committing ourselves, in our teaching practices, to procedures and viewpoints which have not yet given fair promise of future usefulness. Frequent discussions of this sort can be made enormously fruitful.

NORRIS W. RAKESTRAW, *Secretary*

BIBLIOGRAPHY OF ELEMENTARY DISCUSSIONS OF (I) THE INTERIONIC ATTRACTION THEORY OF ELECTROLYTES, AND (II) MODERN THEORY OF ACIDS, BASES, AND SALTS

Compiled by LAURENCE S. FOSTER

Brown University, Providence, R. I.

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* Recommended for general background, but not specifically on the topic.

W. O. Brooks
A. T. Burtsell
R. K. Carleton
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ABSTRACTS

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C. M. Pruitt
Leopold Scheflan
A. A. Vernon
E. D. Walter
Sidney Weinhouse
G. H. Woollett

KEEPING UP WITH CHEMISTRY

Rubber from alcohol. Anon. *Ind. Eng. Chem., News Ed.*, **14**, 243 (1936).—A reprint from the *Chemical Trade Journal*, **98**, 340 (1936), describes a synthetic rubber process in Russia. It is made from 90 per cent. alcohol by the S. K. B. process. Butadiene is made from ethyl alcohol by subjecting it to a temperature of 400° to 450°C. in the presence of both water-splitting and hydrogen-splitting catalysts. The highest yield of butadiene obtained is 30 per cent. by weight. The butadiene is charged into an autoclave chamber into which are suspended zinc rods which have previously been dipped into molten sodium. After charging, the autoclave is heated to 30°C., at which temperature the polymerization reaction starts. The polymerization takes 90 to 120 hours at 65°C. and 8 atmospheres pressure. Toward the end of the reaction the temperature falls to 40°C. and is maintained thus for 3 to 8 days to ripen the rubber. The unreacted materials are removed from the rubber by heating.

A. A. V.

Power-alcohol controversy gives way to broader chemurgic program. Editorial Staff Report. *Chem. & Met. Eng.*, **43**, 315–7 (June, 1936).—The second Dearborn Conference of the Farm Chemurgic Council discussed the whole range of industrial products and processes dependent upon agricultural raw materials from soy beans and oat hulls for plastics and cotton for rayon and roads to such new crops as oak trees for cork, Jerusalem artichokes for alcohol, and pyrethrum flowers for insecticides. In connection with the power-alcohol problem it was said that if the 33⅓% alcohol fuel marketed in England by the American affiliates of the Standard Oil Company of New Jersey and the Cities Service Company were adopted in this country it would mean putting 90,000,000 acres and 6,000,000 unemployed back to work.

J. W. H.

Strong sulfuric acid from wet sulfur dioxide. H. E. Woisin. *Chem. & Met. Eng.*, **43**, 301–2 (June, 1936).—Recovery of sulfuric acid from wet sulfurous gases can be effected by a new process known as the "wet catalysis" process. The SO_3 gases are not absorbed in concentrated sulfuric acid as in the usual contact process but are subjected, together with the water vapor, to fractional condensation. This results in the complete condensation of the SO_3 but only partial condensation of the water vapor. Gases especially suitable for this process are those that originally or through reaction contain water vapor. Vanadium mass is an excellent catalyst for converting the SO_2 into SO_3. By this process many gases heretofore regarded as waste gases may be utilized.

J. W. H.

Poisons for rodents discussed at British meeting. Anon. *Chem. Industries*, **38**, 509 (May, 1936).—Conclusions to be drawn from the general discussion are as follows: (1) Hydrocyanic acid gas, usually produced from calcium cyanide dust or a kindred product by hydrolysis, is the most humane and also the most effective poison when blown into the burrows of rats and rabbits. Out-of-doors it can be used by any responsible person, but indoors it is dangerous to human life except in the hands of experts. (2) All the bait poisons at present in use by the general public act very slowly, taking from one to three days to kill, with the exception of strychnine. (3) All such poisons inflict severe pain; but opinions appeared to differ as to whether this is true of red squill. (4) Research with a view to the discovery of more humane poisons might take the direction either of the addition of a suitable narcotic, as suggested by J. W. Wright, or of an endeavor to identify the rat-toxic component of red squill, and to develop a compound of similar type which would act more quickly.

A. T. B.

Phthalic anhydride. C. R. Caryl. *Chem. Industries*, **38**, 461–4 (May, 1936).—In 1934, 20,600,000 pounds of phthalic anhydride was produced in the U. S. A., according to the U. S. Census of Dyes, and an estimate of 25,000,000 pounds in 1935 would probably be a fairly close one. These figures emphasize again the increasing importance of this organic chemical and fulfil a prediction which appeared in *Chemical Markets* for April, 1927, in "A Decade's Development in Phthalic Anhydride." The author, J. M. Selden, Jr., reviewed the rapid growth in demand for phthalic anhydride from 1917, when 138,000 pounds was produced in this country, to 1927 when production totaled over 4,500,000 pounds. That article concluded, "It might be well for no research organization to overlook this moderate priced organic acid, as the development of new processes for the use of phthalic anhydride in the next ten years bids fair to assume large proportions."

Production of phthalic anhydride by the direct oxidation of naphthalene with air over a catalyst was developed by Gibbs and Conover in September, 1916, in the Color Laboratory of the U. S. Bureau of Chemistry, during the Government's war-time investigation of the manufacture of dyestuffs and intermediates. In 1917, phthalic anhydride had an average market price of $4.23 per pound, the product being made by the sulfuric acid and mercury process. The following year, when phthalic anhydride from the air-oxidation process was first put on the market, the price dropped to an average of $2.85 for the year. Since then, annual increases in output together with process improvements have justified lower and lower prices, until phthalic anhydride is now the cheapest aromatic acid on the market.

A remarkable coincidence was the development of the same basic process by an inventor in Germany, at almost exactly the same time that Gibbs and Conover made their invention. Alfred Wohl applied in 1920 for a U. S. patent covering this process, claiming invention in Germany in the summer of 1916. There was some doubt whether his invention had been made two months earlier or three days later than the Gibbs and Conover invention, but in July, 1934, the U. S. Court of Customs and Patent Appeals rendered a decision in favor of the German inventor, allowing Wohl's claim filed with the German patent office on June 28, 1916, a document which in our patent office would be considered as a new application. Therefore, Wohl's basic patent covering the air-oxidation process was upheld, and he was granted U. S. Patent No. 1,971,888, issued August 28, 1934, assigned to the German I.-G.

The air-oxidation of naphthalene sounds like a very simple reaction. All that is necessary is to vaporize molten naphthalene, mix the vapors with hot air, pass the mixture over a suitable catalyst, and condense the resultant phthalic anhydride, using the heat given off during the reaction to melt more naphthalene and preheat more air. However, the early investigators found out—to their sorrow—that naphthalene had different ideas as to its own behavior. Its preference was not for a dignified union with two oxygen atoms and a change in name to alpha-naphthaquinone, then a break in its first ring, a welcome to one more oxygen atom, and another change in name to phthalic anhydride, each time saying farewell to one molecule of water. Not at all. It would not even care to become maleic or benzoic acid. It very much preferred, after being sufficiently heated, to grab all the oxygen within reach and to become carbon dioxide and water, wasting no more time about it than would gasoline. In fact, this preference was strong enough to scatter one of the first plants over a good deal of landscape.

The problem has therefore been largely a delicate matter of heat control. Start the naphthalene burning. But put the fire out at just the right instant, for vapor-phase oxidation and combustion are synonymous. The process for making phthalic is actually the interrupted combustion of naphthalene.

While phthalic anhydride was developed for use by the infant dye industry during the war, resins and esters are now a far more important outlet than are dyes and intermediates; resins alone accounting for the major portion, with esters, dyes, and intermediates, and miscellaneous uses following in order of their importance.

A. T. B.

HISTORICAL AND BIOGRAPHICAL

Honor where honor is due. ANON. *Laboratory*, **7**, 66–7 (1936).—Although Friedrich Wöhler has generally been recognized as the first to produce aluminum in the metallic state, recent researches have revealed that this distinction should really go to the Danish scientist Hans Christian Örsted.

It has now been proved beyond any reasonable doubt that Örsted actually succeeded in isolating this elusive metal in 1825, two years earlier than Wöhler, who made his experiment in 1827. Örsted first produced the chloride of aluminum by passing chlorine gas over a red-hot mixture of aluminum oxide and charcoal. This oxide in turn he reduced by heating it with potassium amalgam, producing an aluminum amalgam, which, when heated in the absence of air, yielded a few pellets of metallic aluminum, as the volatile mercury was driven off.

Two years later, in 1827, Wöhler, one of the most famous among nineteenth century chemists, repeated this experiment, but with negative result. Urged by Örsted himself he continued the work, and using metallic potassium instead of the amalgam he finally succeeded in reducing the aluminum chloride to the metallic state. As a result of this work Wöhler became generally accepted as the discoverer of metallic aluminum.

In 1925, at the Centenary of Örsted's discovery, his experiment was repeated at the University of Copenhagen. This work has been described in detail in an article by I. Fogh, in the Publications of the Royal Danish Academy of Science.

To the scientific world Örsted will always be known as the discoverer of electromagnetism. Although this one achievement was sufficient to insure Örsted a place among the great scientists of the world, and brought him the honor and influence which he so well deserved, there is no reason why he should not also receive proper credit for his work with aluminum now that the actual facts of the case have been revealed. A. T. B.

Contribution to the history of chemical apparatus. THIENE. *Chem.-Ztg.*, **60**, 16–7 (Jan. 1, 1936).—The glass industry is one of the oldest known. Some glass dates back to 3500 B.C. Old Egyptian glass contains 60–72% SiO_2, 3–10% CaO, 0.8–2% Al_2O_3, and the rest alkalies. Up to the end of the 18th century most glasses contained calcium alkalies. Lead glass was introduced during the middle ages. Chemical laboratory glass used in 1879 contained 0.2% $(AlFe)_2O_3$, 77–79.1% SiO_2, 5–6.4% Na_2O, 6.7–7.7% K_2O, and 7.6–10.3% CaO. At that time Otto Schott gave new properties to glass by the introduction of new elements, as, *e. g.*, Jena normal thermometer glass 16III, a sodium, aluminum, calcium-zinc borosilicate. The development of other glasses is described, and analyses and properties of the new glasses are given. L. S.

Contribution to the history of ink. W. LEONHARDI. *Chem.-Ztg.*, **60**, 125–7 (Feb. 8, 1936).—Preceding the Christian era the Chinese were most advanced in the science of ink-making, with their famous Chinese ink consisting of carbon black mixed with animal glue. During the middle ages the monks used iron gallus compounds in solutions which were unstable because of the absence of stabilizers in the suspensions. A formula of 1412 calls for wetting finely powdered gallus apples with rain water or beer, adding iron vitriol, and filtering after several days. Robert Boyle laid the foundations of the modern ink chemistry. Lewis and Ribaucourt found that when an iron vitriol solution is mixed with aqueous gallus extract an insoluble precipitate is formed, leaving in suspension a very black material. Scheele discovered in 1785 that when a gallus apple solution is exposed to the air a crystalline salt is formed, now known to be gallic acid. Tannic acid was found to be a distinct compound and differentiated from gallic acid, in 1793 by Deyeux and 1795 by Seguin. In 1847 Runge invented his chrome logwood ink by treating logwood extract with potassium chromate. The origin of modern inks dates back to 1856, when August Leonhardi introduced alizarin ink—a stable, clear, colloidal dispersion. L. S.

EDUCATIONAL MEASUREMENTS AND DATA

Students' university choices. S. M. COREY. *J. Higher Educ.*, **7**, 207–11 (Apr., 1936).—A number of studies have been reported summarizing the purposes freshmen give for desiring a college education. While many of the reasons stated are rather nebulous, such as "to get an education," "to become educated," or "to advance in learning," they do represent an attempt made to investigate this important problem from the students' point of view. The author, however, has been able to locate but one study undertaken to determine why students select a particular college from the large number available. That this choice results in considerable confusion to students is recognized by those familiar with the experiences of college recruiting agents.

A casual examination of catalogs makes possible a number of interesting inferences as to the nature of the factors which, in the opinion of college and university officials, should be responsible for a student's decision to attend a particular institution. It would appear that such institutions believe themselves more attractive than their competitors because of superior faculties, that is, the number of men and women with Ph.D. degrees or similar qualifications; the variety of the courses offered; the economy of attending the institution; the completeness of the physical plant; the size of the institution, which means that some schools are fine because they are small and others because they are large; the institution's traditions; its social life, including the fraternities and clubs which students may join; its unique curricular plan or administrative organization; athletics; the institution's location; and lastly, its ideals and moral atmosphere.

These reasons for choosing a particular university or college, however, are usually advanced by administrative officers or faculty members connected with the institutions and may or may not bear any relationship to the real factors which influence students. These latter can only be determined by interrogation.

In order first to prepare a check list of reasons for choosing a particular university, the author made the following inquiry of 143 freshmen enrolled in the Teachers College at the University of Nebraska who were not living in Lincoln: "What factors influenced you to attend the University of Nebraska rather than some other institution of higher learning?" After this question was asked, an opportunity was given the students to comment upon it with the result that many influences were mentioned.

When the discussion was terminated the students wrote down the influences which had been exerted upon them. The following seven, named in order of the frequency of their mention, include over 90 per cent. of all that were given: high-school teachers and administrators; proximity of the university to the students' homes; family; prestige of the institution; economy; availability of desired courses; and friends.

One is impressed, after even a cursory survey of the reasons given by these freshmen electing to matriculate in the University of Nebraska rather than some other institution of higher learning, with their naïveté. There was little indication of careful, intelligent appraisal of the opportunities and facilities provided by available, similar institutions. A. T. B.

FOREIGN CHEMICAL AND EDUCATIONAL CONDITIONS

Training chemical engineers in Germany. A. W. SCHMIDT. *Chem. & Met. Eng.*, **43**, 253 (May, 1936).—Germany is still holding fast to her traditional system of training graduates for the chemical industry. This classic curriculum for the chemist has given positive proof during the last decades of being exceedingly well adapted to German conditions. Within the last few years, however, the impression is gaining ground that increasing importance of design and construction of chemical equipment demands a revision of the curricula. Changes are imperative and serious resistance is expected neither from industry nor from university interests. The Ministry of Education has approved and is supporting the reform movement. J. W. H.

French engineering training is graduate school function. A. TRAVERS. *Chem. & Met. Eng.*, **43**, 261 (May, 1936).—France has about 20 graduate schools, mostly connected with universities, which provide full courses in chemical engineering. The rules for admission are not uniform but, in general, passage of the requirements of the bachelor's degree in mathematics is requisite.

Time given to laboratory work should be at least equal to that devoted to theoretical instruction.

Other requirements for the chemical engineer are sketching, correct interpretation of plans and drawings, design and calculation of equipment implying a certain knowledge of materials and their characteristics. Plant experience during the course is an absolute necessity. J. W. H.

RECENT BOOKS

SALTS AND THEIR REACTIONS. *Leonard Dobbin*, Reader-emeritus in Chemistry, and *John E. Mackenzie*, Reader in Chemistry, University of Edinburgh. Sixth edition. E. and S. Livingstone, 16 Teviot Place, Edinburgh, 1936. ix + 246 pp. 1 fig. 14 × 21 cm. 6/-net; postage 6d.

The present edition of this work is an outgrowth of the earlier attempts to provide an adequate guide for students in the laboratory to supplement a systematic course of experimental lectures. The book was first published in 1904 under the present title, but this first edition was an enlargement of a series of "Notes on Reactions of Salts" which had its beginning in 1889. As later editions of these compilations appeared, the scope of the work was gradually increased by the inclusion of new topics and new material.

In its present form the book is much more than a simple laboratory guide since it contains brief but satisfactory theoretical discussions pertinent to the laboratory sections. The thoughtful student will find in its pages a guide to an interesting journey through a series of laboratory explorations, as well as a stimulating summary of the theories involved. The arrangement by sections makes it easy for an instructor to follow any desired order of development.

The scope of the book may be judged from the following list of topics:

I. Nature and Properties of Salts. This is a theoretical discussion of solutions and reactions, including electrolysis, osmotic pressure, ionization, acids, bases, common-ion effect, indicators, pH, hydrolysis, polybasic acids, and other similar topics.

II. General Methods of Preparing Salts; action of various acids, direct combinations, oxidation, reduction. This section includes a series of laboratory problems, using the methods which are outlined. Several excellent quantitative determinations are included.

III. (*a*) Reactions of Metallic Radicals, including those commonly studied in qualitative analysis.

(*b*) Reactions of Acidic Radicals, including the common acid radicals; schemes for the detection of a single salt and for the separation of the metallic radicals into eight groups.

IV. Dry-Way Reactions—flame tests, films, beads, match tests, sublimation tests, blowpipe tests, concluding with directions for the examination of solid substances.

V. Volumetric Analysis—theoretical introduction followed by eighteen laboratory problems of various types.

VI. Experiments with Some Common Organic Substances, including twenty materials which are commonly encountered in daily life.

VII. Notes on the Commoner Reagents.

There are included also a list of apparatus needed in carrying out the experimental problems, an index, a table of solubilities, and a table of atomic weights.

The book will be very useful in a general survey course, since it offers an excellent and stimulating introduction to inorganic and analytical chemistry. American teachers will find it useful because of its originality, dependability, and the numerous new viewpoints which are presented.

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PHYSICAL CHEMISTRY. *F. H. MacDougall*, M.A. (Queen's), Ph.D. (Leipzig), Professor of Physical Chemistry, University of Minnesota. The Macmillan Company, New York City, 1936. ix + 721 pp. 97 figs. 14 × 21.5 cm. $4.00.

This book is planned primarily as a text for students intending "to become teachers of chemistry, research chemists or chemical engineers." That is, the content and arrangement are such as would be looked for in a first-class senior or graduate course in the subject. The physical and mathematical requirements are reasonable, the fundamentals of calculus and a year of college physics being necessary but sufficient prerequisites. However, graduate students in the biological sciences, soils, geology, metallurgy, etc., should certainly be familiar with the subjects presented and will not find this work too difficult.

The arrangement is orthodox, that is, the order of presentation is essentially that followed by the majority of teachers. The first law of thermodynamics is discussed even before gases, while the second law occupies its usual place before solutions. This separation has certain advantages although some may feel that the loss outweighs the gain. The principal innovation is the placing of the chapters on the electron, radioactivity, atomic structure, quantum theory, radiation, etc., after solids. Dr. MacDougall believes that this is justified as leading to a better understanding of later topics and also arousing interest early. Users of the text not agreeing with him can relegate these subjects to the end of the course, as usual, without in any way disturbing the continuity of thought.

The manner of presentation is very good. Without being verbose, the author contrives to be quite clear. His arguments are presented in orderly fashion and his conclusions are logical. Particularly praiseworthy is the insistence on the limitations and approximations inherent in most laws and relationships of physical chemistry. The book thus presents our knowledge of physical-chemical phenomena as growing but far from complete. Elementary thermodynamics is used extensively throughout. It is woven in as an integral part. This is as it should be and what would be expected of the author of a well-known work on the subject. However, the kinetic view is not ignored or minimized. Both treatments are used in a coördinated manner to present a more intelligible picture of the whole.

No subject that really ought be considered in such a course is omitted. Also it cannot be said that the writer's specialty is overemphasized. Hence it is difficult to praise one chapter above another. The comparison of the van der Waals and Dieterici equations of state is unusual but valuable. The Debye-Hückel equations are discussed and (rare in such a book) derived. Illustrations are numerous and well chosen. One hundred thirty tables of data enhance its value. The author, in discussing electrochemistry, differentiates between electromotive force and potential difference. He hopes thereby to clarify the confusing subject of conventions as to sign, etc. In the reviewer's opinion this is an unnecessary refinement. Excellent conventions, arbitrary in certain respects but thoroughly satisfactory, have been extant for years. The system proposed does not seem a real improvement. Nevertheless the whole chapter on electrochemistry is treated in a most excellent fashion. The references throughout are adequate for this type of text. Each chapter is concluded with a list of books for recommended reading and an abundance of problems for solution. The answers to the latter might be included, but this seems to be a common omission. Numerous experimental methods are described, as a rule with sufficient detail. A greater number of figures illustrating the apparatus used could have been included with profit.

In conclusion, it may be said that this text will provide a thorough, fundamental training in physical chemistry. It will also serve as a reference adequate for numerous purposes. It rivals the best works of its kind in use at present and merits careful examination by every teacher of the subject.

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THE STUDENT'S MANUAL OF MICROSCOPIC TECHNIQUE, WITH INSTRUCTIONS FOR PHOTOMICROGRAPHY. *J. Carroll Tobias*. American Photographic Publishing Co., Boston, Mass., 1936. xvii + 210 pp. 79 illustrations. 15 × 23 cm. $2.50.

This clearly written and attractively illustrated little manual

can scarcely be regarded as a textbook for the chemical microscopist. For the student, however, who wishes to acquire a working knowledge of general microscopy, or for the person who desires a reliable guide to the technic of one of the most fascinating of all hobbies, it is to be recommended without reservation. The directions for photomicrography are particularly good.

One feature of the book will appeal especially to the hobbyist: although the reader is introduced to commercial professional equipment and accessories, numerous suggestions for the home-construction of inexpensive yet practical substitutes are offered.

OTTO REINMUTH

ELEMENTARY PRACTICAL CHEMISTRY. *Arthur I. Vogel*, D.Sc. (London), D.I.C., F.I.C., Head of Chemistry Department, Woolwich Polytechnic. Blackie & Son, Limited, London, 1936. 220 pp. 73 figs. 12.5 × 18.5 cm. 3s.

In the preface to the 163 experiments of this laboratory manual the author describes his work and viewpoint as follows: "A fairly comprehensive series of experiments in somewhat greater detail than is usual in laboratory manuals of this kind is given: a brief description of the underlying theory is included in order to bring home to the student the real purpose of the experiment. It is the author's view that a sound foundation of the principles of practical chemistry (and simultaneously a better appreciation of his theoretical work) is best provided by giving the student full working details of the correct methods of carrying out experiments, and the so-called research method is best postponed to a later stage." The author's description is accurate and he is to be commended on the success with which he has met the specifications of his preface. Not only are the details of procedure carefully given but also in most cases the results are described, and balanced equations are provided. One is delighted to find many new and ingenious experiments among the old favorites.

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ELEMENTARY PRINCIPLES IN PHYSICAL CHEMISTRY with Special Reference to the State of Equilibrium in a Chemical Reaction and to the Rate of Attainment of the State of Equilibrium. *T. J. Webb*, Assistant Professor of Physical Chemistry in Princeton University. First edition. D. Appleton-Century Company, Inc., New York City, 1936. x + 344 pp. 26 figs. 67 tables. 15 × 22 cm. $4.00.

According to the preface: "This textbook has been written as an introduction to the subject of physical chemistry primarily for juniors and seniors in college. It has been assumed that such students would have had preliminary training in the descriptive phases of chemistry, in general physics, and in the calculus .... It has been the purpose of the author to introduce the principles and to make the derivations in a manner sufficiently general that they would not stand in need of constant revision as more advanced stages of the subject are reached. As an inevitable result the treatment is to some extent analytical and mathematical ....."

That this is not "just another physical chemistry textbook" is evident from a mere listing of the chapters: "Introduction, The First Law of Thermodynamics, Chemical Equilibrium, The Second Law of Thermodynamics, Equilibrium between Phases, The Thermodynamic Properties of Strong Electrolytes, The Rates of Chemical Reactions, and The Quantum Theory." Among the departures from the usual field of the "elementary" text are: rather detailed mathematical discussions of Maxwell's distribution law, Boltzmann's principle, mean free path, number of collisions, and the viscosity of gases. The heat capacity of gases is rather thoroughly discussed from the point of view of the separate contributions of translation, rotation, and vibration, and the quantization of the energy, particularly that of vibration. In the treatment of the Debye-Hückel theory, Poisson's equation is first developed in considerable detail. The mathematical details of the simpler theory are then given with great care. The chapter on the quantum theory (46 pp.) deals with the electron in its particle and in its wave aspects, with Schrödinger's equation, with the energy states of a free particle, a particle in a box, the harmonic oscillator, and the rotating diatomic molecule. The discussion is closed with the correlation of Pauli's exclusion principle with the numbers of electrons in the various shells, and with their quantum numbers. Errors, typographical and otherwise, are remarkably infrequent for a first printing.

The reviewer fears that the average undergraduate student of physical chemistry lacks the preparation and the ability to profit greatly by the use of this book, and that its use with such students would lead to feelings of discouragement and despair. The book should, however, be of very great service in an "honors course" or in a course for graduate students who have already had a beginning course in physical chemistry. But even in these cases the teacher should be able and willing to give the students material help in the more difficult places, and should frequently supplement the very general discussion in the text by additional specific and concrete examples.

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STUDY UNITS IN GENERAL CHEMISTRY—A Laboratory Manual. *W. E. Bradt*, Ph.D., Assistant Professor of Chemistry, State College of Washington. D. Appleton-Century Co., New York City, 1936. xvii + 178 pp. 15 × 22 cm. $1.50.

The author's purpose (stated in an accompanying "Guide for the Instructor") is to subdivide chemical instruction into groups of topics, each presenting a definite task; to develop systematic reading habits; to create interest in chemistry, through references to books or journals in popular style; to foster efficient individual instruction. The experiments described are of a simple type, suited to high-school students or beginners in college work. They are in no sense unusual or original, but manipulative directions are carefully set forth, and numerous references to current textbooks are given.

Thirteen of the twenty "study units" may be classified as descriptive chemistry of the individual elements and compounds, and only six relate to simple theory, such as the approximate determination of atomic weights by the law of Dulong and Petit, combining proportions by weight, molecular weights, volumetric titrations, and the periodic law. Many teachers would wish more attention paid to such fundamental matters as chemical equilibrium, catalysis, the nature of acids and bases, oxidation and reduction, electrochemical principles, the choice and use of indicators.

This book raises many interesting pedagogical questions, which different teachers will answer in different ways. Should the topics of descriptive chemistry be classified under individual elements or would it be better to present them as illustrations of general principles? Should laboratory work be intimately interwoven with a study of reference texts, or should it be made to develop something different in nature from that developed by the study of any text, namely, the capacity *to observe and to reason from what is observed?* Should a laboratory manual include any questions that may be answered merely by looking up the answers in a textbook? Is there any danger that balanced chemical equations, introduced too early, may tend to make chemical study a species of algebra, and interfere with training in capacity to observe and to reason from what is observed? Should not a laboratory manual become more difficult, and manipulative directions more brief and concise, as the student makes progress through it? Is not laboratory work intended to give training in the application of the scientific method; if so, should not laboratory exercises present real problems, to be solved by observation and inference, rather than facts of descriptive chemistry to be verified? Is the resolution of a science into disconnected "study units" chiefly to be recommended because it tends to make the instructor's task an easier one or because it helps the student to see relationships that would otherwise be missed? If the latter is true, is there not danger that equally important relationships, which happen to cross the boundaries between arbitrarily chosen "study units," may be obscured? Should not many experiments, heretofore usually included in laboratory

manuals—such as the preparation of gaseous hydrogen and oxygen—be dropped from instruction, to make room for general concepts of growing importance, such as acid-base and oxidation-reduction equilibrium?

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LEHRBUCH DER CHEMIE FÜR HÖHERE LEHRANSTALTEN. (Textbook of Chemistry for Secondary Schools.) Part 1. *Rudolf Winderlich*, Head of the Board (Oberstudienrat) at the Oberrealschule, Oldenburg in Oldenburg. Fifth revised edition. F. Vieweg und Sohn, Braunschweig, 1936. vi + 143 pp. 15 × 22 cm. 80 figs. 2.88 R.M., bound.

This is the fifth edition of a book that has been used since 1921. In order to provide pleasant and instructive reading for young students, Professor Winderlich has omitted some material that appears in most textbooks of chemistry and has introduced brief and appropriate citations from the scientific classics. The familiar metals and solid non-metals are introduced before the gases. Chemical formulas and equations are used only in the last two-thirds of the book. Roman, italic, and bold-face type and the customary double-spacing for emphasis clearly differentiate the descriptive and experimental portions without the use of any unpleasantly small type. Most of the experiments are marked *SV* (Schülerversuch), but a few of the more difficult ones are marked *LV* (Lehrerversuch).

In connection with the experiment on the ignition of limestone, the students learn that, centuries ago, the Roman architect Vitruvius mentioned the loss of weight which they have just observed. They then repeat several of Joseph Black's famous experiments which led to a correct and complete explanation of this reaction.

The discussion of combustion is interspersed with citations from the original papers of Scheele and Lavoisier. The atomic theory is introduced by an appropriate quotation from Lucretius' famous poem, "On the Nature of Things," translated into German verse by Goethe's friend, K. L. von Knebel.

The book contains valuable information about German chemical industries. The first boring for salt was made in 1812 at Jagstfeld near Wimpfen on the Neckar after a sinking of the earth's crust at Möckmühl had unexpectedly exposed the rock salt. The boring at Stassfurt was begun in 1839, and the salt was not reached until four years later. These great deposits of potassium salts have been productive since 1857.

Professor Winderlich emphasizes the practical aspects of chemistry, and, in this book for beginners, makes no mention of the dissociation theory. The seven-page supplement on protection from fire and poisonous gases contains fire-extinguishing experiments which might well be included in every course in general chemistry.

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LEHRBUCH DER CHEMIE FÜR HÖHERE LEHRANSTALTEN. Part 2. Advanced Course. *Rudolf Winderlich.* Third revised edition. F. Vieweg und Sohn, Braunschweig, 1932. viii + 297 pp. 15 × 22 cm. 198 figs. 6.40 R.M.

This is the third edition of a book which first appeared in 1924. Since it is intended for students who have completed the elementary course presented in Part 1, it contains many quantitative experiments, detailed descriptions of many industrial processes, and valuable information on the economic aspects of chemistry, especially in Germany.

The chapter on the noble gases has an interesting historical introduction. At the beginning of the nineteenth century the Munich Academy of Sciences offered a prize for the solution of the problem as to whether or not nitrogen liberated from its compounds is identical with that of the atmosphere. This was not solved, however, until nearly a century later, when Lord Rayleigh's masterful determinations of the density of nitrogen led to the discovery of argon.

In the chapter on sulfur there is a clear description of the remarkable Frasch process of melting sulfur underground and pumping it to the surface, which gave the otherwise inaccessible deposits of Louisiana their supremacy over the ancient Sicilian ones. After the student observes the deposition of sulfur caused by the action of sulfur dioxide on hydrogen sulfide, he reads Bunsen's description of the hot springs of Iceland, in which Nature performs the same experiment on a grand scale. The harmful effect of sulfur dioxide in the atmosphere is illustrated by the corrosion and breaking of copper telephone wires in Berlin and the damage to the Cologne Cathedral.

Dr. Winderlich shows how world supremacy in copper production has shifted throughout the centuries from one country to another. In ancient times Egypt, Carthage, Numidia, and Cyprus were the great producers; in the fifteenth and sixteenth centuries Tyrol and Hungary ruled the market; during the seventeenth, the great Fahlun Mine in Sweden held sway. In more recent times Russia, Cornwall, and Spain have successively played the leading rôle, and at present the United States produces more than half of the world's output of copper.

The dissociation theory is briefly discussed, and some of the equations in the latter half of the book are written in the ionic form.

The last eighty pages are devoted to organic chemistry. The importance of combustion methods of analysis is emphasized by a quotation from Liebig: "For the analysis of seven organic acids, the former [Berzelius] required eighteen months, and M. Chevreul worked thirteen years on the analysis of the fatty substances he discovered. With the aid of our present method, Herr Berzelius would have required only four weeks at the most and M. Chevreul perhaps two years instead of thirteen."

The following statement is quoted as Lavoisier's first chemical equation: "Grape must = carbonic acid + alcohol." The chemistry of ethyl alcohol and the technology of brewing and distillation are discussed in detail. The author states that Germany is suffering from overproduction of alcohol, much of which is unfortunately consumed in the form of beverages. He observes that neither high taxation in Germany nor prohibition in the United States has succeeded in controlling this evil.

American students who are learning to read scientific German will enjoy Professor Winderlich's pleasant literary style and clear expositions and will be interested to learn how modern German chemists are meeting their difficult economic problems.

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DIFFERENTIAL EQUATIONS IN APPLIED CHEMISTRY. *Frank Lauren Hitchcock*, Ph.D., Professor of Mathematics, and *Clark Shove Robinson*, S.M., Associate Professor of Chemical Engineering, Massachusetts Institute of Technology. Second edition. John Wiley & Sons, Inc., New York City, 1936. viii + 120 pp. 12.5 × 18.5 cm. $1.50.

Any chemist who has had a course in the fundamentals of calculus can easily comprehend and profit greatly from a study of this practical little book. The illustrative examples are clearly explained and the exercises cover subjects ranging from chemical kinetics and flow of liquids to growth of population and interest rates. Emphasis has been placed, not only upon the expression of the problem in the form of a differential equation, but also upon the various ways in which the numerical calculations can be accomplished.

The second edition has many new problems and the old ones have been revised along with the insertion of data from recent literature. The discussion of Fourier series has been amplified and a chapter has been added in which the numerical solutions of differential equations of types difficult to integrate are discussed.

Every student of chemical engineering should own a copy of this book. Many of the problems and methods could well be incorporated into the standard year's course in physical chemistry.

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